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Success factors for information technology supported international technology transfer: Finding expert consensus

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Abstract

Information technology (IT)-supported international technology transfer (ITT) is complex, risky, and fails often. No empirical studies are available on the factors that affect the success of IT-supported ITT. We review applicable theories (i.e. diffusion of innovation theory) and empirical research in conventional technology transfer to develop such a model. We carry out a multiple focus group method to rank factors that affect the success of IT-supported ITT and then apply a branch and bound method to derive a consensus ranking of these factors. The identified consensus ranking sheds light on factors that are similar to those of DOI theory and suggests a pattern of factors that affect IT-supported ITT.

Keywords: Success factors; IT support; IT implementation; International technology transfer; Diffusion of innovation; Consensus ranking

1. Introduction

Companies invest a high percentage of their turnover into research and development (R&D) as technology life cycles become shorter and markets increasingly competitive, and turbulent [22,28,32,33]. The Internet and associated telecommunication services such as teleconferencing and electronic data interchange (EDI), electronic banking, and resulting improved logistics have created more open environment for companies to operate globally. As a result companies significantly globalize their operations and manage shortened technology life cycles through international technology transfer.

International technology transfer (ITT) has become an important research topic in technology diffusion [1,3,22,31,38]. Successful ITT provides benefits for all parties including suppliers, technology supplying countries, technology receivers among others [1,22,31,38]. Yet, ITT is complex and risky [1,22,38] due to the complex processes, dynamism of the technology, low technology absorption capacity of recipients [1,29], and demand for significant resources (e.g. financial, human

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and physical resources) [38]. Due to these challenges companies carrying out ITT often fail to maintain schedules, manage costs, and achieve quality, and many projects end up being cancelled [22,31].

Information technology (IT) can help resolve some of the difficulties associated with international technology transfer[1] [30]. In particular global networks and new training tools are more readily available and easier to use, thus providing for speedier and more secure transfer of technology.

IT-supported ITT[2] demands new resources and capabilities in place to be successful. Yet there is paucity of studies that analyze factors that affect the success of IT-supported ITT. This study seeks to fill this gap. We will seek to identify a list of factors that affect the success of IT-supported ITT. The main research questions are the following: what are the factors that affect the success of IT-supported ITT? What is the relative significance of different factors? And how can we determine such relative significance?

The remainder of the paper proceeds as follows. We carry out a literature review on technology transfer in Section 2. Section 3 formulates a framework for factors affecting IT-supported ITT. The research methods applied in this study are described in Section 4. Section 5 briefly describes four investigated high-tech companies. Section 6 evaluates and ranks factors by using a multiple focus group method and a recursive branch and bound method. Finally, conclusions and implications are discussed in Section 7.

2. Literature review

We conceptualize technology as knowledge systematically applied, as well as the skills and competencies of individuals and teams [1,3,31,38]. In addition, technology involves the work-organization that enables the innovative design of products, services, efficient production being brought to market quickly, practical solutions to problems, etc. We define high technology as that which requires high utilization of scientific manpower, engineering manpower, and extensive R&D expenditure to be at the forefront of technological leadership [8,10,31]. High technology is expected to change relentlessly, and its life cycle is expected to become shorter while markets grow competitive.

2.1. International technology transfer

We define international technology transfer as a process by which a technology supplier communicates and transmits the technology through multiple activities to the receiver, across national borders. This will ultimately enhance the technological capability of the receiver [1,3,31,38]. We view ITT from a holistic perspective of both technology transfer and utilization. ITT is not a singular event but rather forms a process that starts with identifying the needs and demands for technology, and follows by activities relating to technology transfer and implementation, and finally culminates in the assurance that the technology has been acquired by the recipient as per plan and schedule.

2.2. Information technology support

Multiple IT tools can support complicated tasks associated with ITT. Information technology can increase capacity as well as decrease costs of information storage, processing, and communication [2]. IT adds value to an organization by providing support to the administrative infrastructure, business processes, and the operational skills of the staff. IT increases global connectivity, overcomes distance, decreases time barriers, reduces communication costs, cuts costs through automation, facilitates information sharing, and facilitates access to the advice of remote experts [22,29, 31–33].

2.3. Factors affecting the success of ITT

We are concerned with the success of an ITT project, where IT is deployed and used. In this study we are interested in factors that contribute to this success. A literature review on ITT reveals that the following factors contribute to success of technology transfer:

[1] In *conventional technology transfer approach*, (transfer of knowledge, skills, and equipment across national borders) several activities are executed such as (a) international market research for technology transfer is conducted by using local trade magazines and visiting foreign countries, (b) the selection of a technology recipient is performed by using external consultants, face-to-face meetings and interviews, (c) negotiations are carried out through face-to-face meetings, (d) transferring of knowledge and skills are facilitated through extensive face-to-face and on the site training, and (e) evaluation and problem solving is done by visiting the facilities of the technology recipient [1,38]. The conventional method requires extensive traveling, is very expensive, and time consuming.

[2] IT-supported ITT process refers to the IT-enabled entire process through which various methods, processes, knowledge, skills, hardware, and software are transferred from the technology supplier to the technology recipient across national borders that allow the technology recipient produce high quality products or services more efficiently [31].

- Adequate financial resource [38].
- Adequate material resources, such as, machinery, equipment, spare parts, etc. [38].
- Adequate technological and managerial knowledge and skills of the technology suppliers [3,38].
- Experience in ITT [1].
- Adequate training [38].
- Controlling [1].
- Language [1].
- Functioning regulatory framework [1,38].

We expect additional factors to emerge that will ensure the success of a technology transfer project when IT is deployed. Identifying these factors is the major aim of this study.

3. A framework for factors affecting IT-supported ITT

An investigation of literature indicates that almost no empirical research has been conducted on factors of IT-supported ITT. Several well established innovation theories like diffusion of innovation (DOI) theory allows us to build up a framework for organizing factors affecting IT-supported ITT.

DOI theory is based on the assumption that people decide independently whether they will accept new things or new ways of doing things. It predicts reasonably well adoption decision by individual adopters who are assumed to make rational choices while adopting discrete and relatively well defined innovations. According to Rogers ([40], pp. 5–11) an innovation is: "the idea, practice, or object that is perceived as new by an individual or other unit of adoption" and the diffusion is: "the process by which an innovation is communicated through certain channels over time among the members of a social system". IT-supported transfer of high technology is a new process and is thus an innovation. As the name suggests, DOI theory deals with innovations and their diffusion into organizations. Recently it has been used to study IT innovations [22,27,31,32,35,39–41]. The "factor approach of DOI theory" assumes that diffusion of innovation is influenced (i.e. affected) by factors, such as the characteristics of the technology, characteristics of organization, or the nature of the external environment. Factor approach identifies factors that relate a set of factors to a particular outcome [36]. The focus of our study is to determine factors that affect the success of IT-supported ITT. In this context the success means that the adoption of IT was successful to yield the desired results. Hence factors affecting the success of IT-supported ITT are also expected to reflect on the factors that affect the diffusion of IT innovations in this context.

DOI theory deals mostly with micro-level factors and therefore it cannot explain the diffusion of complex innovations. To overcome this limitation, researchers have recently extended DOI theory by integrating it with other theories to account for the IT innovation diffusion [9,31]. We undertook an extensive field study to identify these other factors that can influence the success of IT-supported ITT.

3.1. Micro-level factors

3.1.1. Characteristics of an innovation

Rogers' [39,40] study shows that an innovation is more likely to succeed if it includes the following characteristics: relative advantage, compatibility, less complexity, trialability, and observability. General research on the implementation of innovations [18], technology innovations [38], and IT innovations [12,34,36] are consistent with Rogers' findings. In addition, innovation characteristics such as ease of use [6] and technology functionality [11] influence the likelihood of adoption.

3.1.2. Characteristics of a company

The characteristics of a company have long been associated with its capacity for innovations [38] and IT innovations [34,36]. The characteristics that promote innovation include: need for the innovation [38], availability of resources (i.e. material resources [17]), knowledge and skills [3,38], financial resources [17,38], time [1], experience [1], management of innovation implementation [31], risk management [21], management support [20], leadership [31], motivation [17], and training [5,20,38].

To conclude, IT innovations enhance the success of ITT. We can use DOI theory and its extensions as a framework to identify and organize factors that affect the success of IT-supported ITT. Therefore DOI theory and its extensions were used in formulating a questionnaire to identify factors that affect transferring technology with the help of IT in an international context.

4. Research design and methods

In order to discern factors for IT-supported ITT, we collected data from a set of companies that were engaged in ITT to improve the conceptual and content validity of factors. In this step we followed a multiple case study method [23]. To this end we identified four suitable companies for our study. The case study included conducted interviews and data collection with a questionnaire. In each case company, we applied the focus group method to solicit information about the conceptual and content validity of the identified factors.

This study investigates ''how'' and ''what'' types of research questions. A focus group method is suitable for ''what'', ''how'' and ''why'' types of questions [16,24]. According to Krueger [16], a focus group is a carefully planned discussion designed to obtain perceptions on a defined area of interest in a permissive, non-threatening environment. Group members influence each other by responding to ideas and comments in the discussion. In the focus group method, group interviews and discussions produce data rich in detail. Participants' views and experiences are expressed through interaction and open discussion. Focus group method facilitates direct dialogue and deep understanding. Social scientists have increasingly employed focus group methods in their research [15,16,24]. For these reasons, a multiple focus group research method (i.e. a focus group method in multiple companies) was selected to conduct this research.

Selected case companies were technology supplying companies and their selection was determined by the following considerations: (1) suppliers of complex and high technologies who are heavy users of IT and have successfully (that is the transfer took place as per time and schedule and the recipient companies were satisfied with the benefits they obtained) transferred technology to various technology recipients around the world and (2) the companies are knowledgeable and willing to share their knowledge, opinions, and insights. The recipients located in India, Thailand, Malaysia and Hungary, were interviewed by using E-mails, conferencing technologies, and telephones.

The focus group participants and interviewees were IT managers, technology managers, business or general managers, and other executives who were either directly involved in the technology transfer projects or were connected to the projects. This provided an adequate number and range of people with diverse experiences covering all aspects of IT-supported ITT.

To investigate the research questions, the informants were asked the following sub-questions:

- What technologies were transferred?
- How successful was the IT implementation and the execution of IT-supported ITT?
- What were the factors that affected the success of the execution of IT-supported ITT? Please give a rank on each factor in the order of importance according to the following scale: 7 (very important) to 0 (not important).
- How did these factors enhance success in IT adoption and the execution of IT-supported ITT?

In each focus group discussion, four to six interviewees took part and each time discussion lasted 4–5 h with a short break. In order to enhance interactions between focus group participants and facilitate open and in-depth discussions among all participants, strict guidelines suggested by focus group methodologists were followed during each focus group session. According to the suggestions in [15,23], several activities were performed to conduct the data analysis for each focus group discussion. Several such focus group discussions (over 16) were conducted with knowledgeable informants in four Finnish technology suppliers (our case companies) during the last years. From each company about seven people were interviewed. These focus group discussions allowed us to gather enough data. Further interviews did not provide any new data therefore the data collection process was stopped. We took field notes during the discussions. We also recorded the discussions, listened tapes, and wrote down the important ideas that were related to the research questions. The transcribed text in particular on the success factors was over 200 pages. In addition, documents such as research reports, market research reports, annual reports, internal company magazines, and articles published in magazines, press releases and other archival materials of both the technology supplying and receiving companies were collected and compared with empirical data. A logbook was used to identify which focus group mentioned which particular factor [15,16,24]. The results were not only based on the logbook, but also on notes made when the transcripts as a whole had been read. This is important as it reduced the possibility of misunderstanding the circumstances under which a particular response was made.

To ensure the validity and reliability of this research, several measures were applied. First, the background theory, a preliminary interview protocol, and a questionnaire guide for focus group method were used in order to deal with detailed documentation of the data to minimize errors and biases. The questionnaire guides were verified by the case companies, focus groups, researchers, and practitioners. Second, it was ensured that selected interviewees were involved in the IT-supported ITT process and possessed a proper knowledge of the phenomenon under investigation. Third, the concepts of this research were delineated to the interviewees before conducting the interviews. This served to improve validity. Fourth, for the focus group method, several participants of each focus group talked in great depth about each issue that was being investigated. Through these in-depth discussions of several participants, data were verified [24]. Fifth, multiple data sources [43] and multiple methods [7] have been used in this study in order to increase the reliability and validity of the research. Sixth, the focus group reports were sent to the interviewees to check for errors and to evaluate the validity of the interpretation [24]. Any errors were duly corrected. Seventh, the same questions were asked to the different focus groups of each company and the results were carefully compared. Comparison was further made with available published materials of the case companies. Finally, the research path for the focus group method has been consistently documented to ensure reproducibility [24]. From four case companies we got four different rankings of the success factors (see FG1, FG2, FG3, and FG4 in Table 1).

5. Case description

Four case companies were investigated in-depth. They have all been able to successfully execute IT-supported ITT several times. This section briefly describes the four companies. These case companies and their industries are characterized by intense R&D, high R&D expenditures, intensive utilizations of IT and manpower (scientific and engineering), short life cycle of the products, and short life cycle of technology.

5.1. Company 1

Company 1, a large Finnish multinational, is involved in servicing the pulp and paper industry. It has transferred pulp and paper industry servicing technology, including related automations, to several advanced industrialized countries (e.g. USA, Germany, France, Japan) and developing countries. The company has a strong presence in Western markets. Through high investments in R&D the company sustains its leading position in technology.

In order to strengthen its position in the markets of South East Asia (SEA) and satisfy local demand, the company wanted to establish a full-service technology centre at a favorable location in SEA from where it could easily gain accessibility to the pulp and paper industry of that region. Through a feasibility study, Thailand was identified as the most favorable location. Company 1 established a plant in Thailand that

Table 1
Factors affecting the success of IT-supported ITT

Factors	Focus group sessions			
	FG1	FG2	FG3	FG4
1. Appropriate and agreed upon specifications of IS	6	4	6	5
2. Standard IT tools	5	4	5	6
3. Appropriate and tested technology (transferred tech.) package that fulfills both the recipient and the market requirements	7	7	7	7
4. Adequate financial resources	7	6	7	7
5. Appropriate and adequate technical experts, technical support staff, and management people from all sides with clear roles and tasks	7	4	7	7
6. Competent project managers	5	3	4	4
7. Appropriate and adequate physical resources (e.g. computer hardware, software, manuals, machinery, equipment, etc.)	6	7	6	5
8. Experience with similar project implementation	4	3	5	5
9. Proactive leadership and management support, and high commitment from all parties including their top managements and personnel	5	4	4	5
10. Open, intensive, and effective communication between the key personnel of all parties	5	4	6	3
11. Effective international coordination	6	5	4	5
12. Effective control and risk management	4	3	4	4
13. Motivating the project participants	4	2	3	3
14. Adequate training and training materials	6	5	6	5
15. Availability of well-trained employees	0	4	0	0
16. Proficient in language	3	5	3	3
17. Positive attitude towards learning	2	1	0	0
18. Reliable IT, telecommunications, and other infrastructures	5	4	5	5
19. Functioning regulatory framework	3	2	2	2

provides specialized technical support, roll services, and spare parts for the pulp and paper industry in SEA market.

The technologies transferred from Finland were especially (a) for paper machine roll coverings and coatings, (b) engineering know-how, and (c) business control systems and practices. These are cutting-edge technologies and adapted according to the needs of SEA market.

The technology was transmitted through the provision of documents and intensive training. The Finnish company trained mainly managers, engineers, and shop floor technicians. This company did not employ a conventional technology transfer method in Thailand due to the complexities, high resource requirements, and slowness inherent in this method. It deployed an IT-supported ITT process and used various IT tools (e.g. ValNet system, Lotus Notes, CAD, ERP, Extranet, project management software, MS office, CD-ROMs, etc.) in each of the phases of its technology transfer process. Thus they successfully executed the process in a cost efficient manner, avoiding some of the obstacles presented by the conventional technology transfer method. In order to ensure quality and survival, the technology supplier is transferring more advanced technology to its SEA site continuously. The factors that affected the success of IT-supported ITT of this company are presented in Table 1.

5.2. Company 2

Company 2 is a large multinational company involved in the manufacturing, installation, maintenance, and modernization of elevators as well as escalators. It continuously upgrades its technology through high investments in R&D. It has transferred technology to Western Europe, North America as well as to developing countries around the world. Mainly, due to saturation of its markets in developed countries (Western Europe and North America) and increased international competition, Company 2 was looking for opportunity in emerging markets.

One prospective technology recipient from India made an enquiry to Company 2 through an organization named Finnish industrial development fund (FIDF). The Indian technology recipient had experience in the manufacture, erection, and maintenance of certain types of lifts.

Company 2 made feasibility and market research studies to evaluate the technology transfer to India. In 1983, it negotiated a favorable technology transfer contract. It contributed technology and owned part of the new company, while FIDF invested money in the new venture. The technology transferred was a combination of product know-how, process know-how, operation know-how, and management know-how. Company 2 arranged training for Indian managers and engineers in Finland and other Western countries. They opened a new factory at the beginning of 1984 in India. After receiving training a few engineers left the company since they were offered higher salaries by other companies.

Company 2 deployed an IT-supported ITT process. At the beginning, Company 2 used ITs on a limited scale in each of the phases of its technology transfer process. Currently, it uses the following ITs to execute an IT-supported ITT: ERP-SAP/3, CAD, databases, E-mail, the Web, the Intranet, the Extranet, project management software, EIS, mobile communication systems, MS office, CD-ROMs, etc. Technological contribution of Company 2 is a crucial element in the growth and profitability of the technology receiving organization. Continuous absorbing of advanced technology ensures recipient's survival. The factors that affected the success of IT-supported ITT of this company are presented in Table 1.

5.3. Company 3

Company 3, a Finnish multinational, is involved in the turn-key delivery of energy production systems and transmission systems. Company 3's computer-aided power engineering facilitates efficient planning process, reliability, and cost efficient operations. Company 3 puts high emphasis on R&D on a continuous basis. Due to its extensive international experience and effective R&D, it has been able to supply innovative technological solutions around the world. It is conducting businesses in Western Europe (e.g. Germany, the UK), Eastern Europe (e.g. Poland, Russia), North America (e.g. USA), Asia (e.g. China, Malaysia, and Thailand) and Africa.

Company 3 scans for business opportunities around the world. Due to the privatization of energy sector in Hungary one such opportunity appeared for Company 3. Hungarian government privatized one state owned power sector engineering company in 1995. Company 3 bought a part of the company. It transferred its latest technology and upgraded the technology of the Hungarian company. The enterprise is located in Budapest, Hungary and is called ETV-Eröterv Rt. There are several old technology based power plants in Hungary. ETV-Eröterv Rt. is upgrading them, making them safer, and improving their performances. Company 3's technology transfer to Hungary has improved the competitiveness of the technology recipient and ensured its survival.

Company 3 also deployed an IT-supported ITT process. It used ITs, particularly in training that increased training capacity and effectiveness. Currently, it uses a number of ITs in executing an IT-supported ITT. Namely: CAD, databases, E-mail, the Web, project management software, mobile communication systems, MS office, CD-ROMs, simulator, simulation-based software, etc. Company 3 is continuously transferring technology to its Hungarian site. The factors that affected the success of IT-supported ITT of this company are presented in Table 1.

5.4. Company 4

Company 4 is a large Finnish Energy Company that upgrades its technology through intensive R&D efforts. It has developed technology for operation and maintenance (O&M) of power stations. By continually upgrading the technology, the company stays ahead of competitors. It has transferred O&M technology in several advanced industrialized countries as well as developing countries. Due to deregulation and privatization, the demand for O&M technology has increased in South East Asian (SEA) countries and other parts of the world. Company 4 made a feasibility study of the potential in SEA markets and desired to enter into SEA markets through transferring its O&M technology.

It negotiated a technology transfer contract with a technology recipient in Malaysia and made several agreements with the recipient. It supplied O&M technology that combines information systems, procedures, and problem solving expertise. The plant in Malaysia came into operation at the beginning of 1995. The plant sells electricity to private companies. Transferring the technology has offered the recipient availability of power, cost efficiency, safety, and a minimum risk of unexpected power plant failure.

Company 4 also deployed an IT-supported ITT process. The knowledge of its technology is transmitted through the provision of documents and intensive training. It provided theoretical training supported by simulators to a few of the employees of the technology recipient in Finland. In addition, a few Finnish experts were sent to Malaysia to provide training. Company 4 extensively used ITs, particularly in training that increased training capacity and effectiveness. Currently it uses a number of ITs in executing an IT-supported ITT. Namely: CAD, databases, E-mail, the Web, project management software, mobile communication systems, MS office, CD-ROMs, simulator, simulation-based software, etc. The factors that affected the success of IT-supported ITT of this company are presented in Table 1.

6. Analysis of factors that affect the success of IT-supported ITT

First, we will present the four rankings obtained from focus group discussions in four companies. Then we will derive a consensus ranking. Then we will observe some comments made by company personnel on the relevance of these success factors.

6.1. Ranking of success factors

Focus group discussion in each company gave us the ranking of factors by that company. Thus we obtained four rankings from the four companies. Each identified "factor" ranked on a scale of 7 (very important) to 0 (not important). Therefore, the importance of the factors in Table 1 ranges over eight levels. In the following table, FG1 denotes the focus group discussion in company 1, FG2 denotes the focus group discussion in company 2, FG3 denotes the focus group discussion in company 3, and FG4 denotes the focus group discussion in company 4.

From Table 1 we can derive preference relations or consensus rankings as defined in Kemeny and Snell [14]. By applying a recursive branch and bound method these factors can be further categorized into a consensus ranking. The selection and application of a recursive branch and bound method used in this study is described in more detail in Appendix A. The consensus ranking (Table 2) is a representative of all the four focus group rankings and it gives us the general representation of factors affecting IT-supported ITT.

After applying the branch and bound method (see Appendix A), we obtained the following linear ranking (in terms of serial numbers of factors in Table 1): $3 \succ 4 \succ 5 \succ 7 \succ 14 \succ 1 \succ 2 \succ 11 \succ 10 \succ 18 \succ 9 \succ 8 \succ 6 \succ 12 \succ 13 \succ 16 \succ 19 \succ 15 \succ 17$. Based on their order of importance the factors are placed in Table 2. A cross (x) indicates that the issue is relevant to the case company.

Many of the identified factors are completely different from those encountered in conventional technology transfer or in general DOI theory. Moreover, the relative importance of these factors is significant. For example, the very first factor is largely ignored in conventional technology transfer, or in general DOI theory. Overall, DOI theory does place a significant

Table 2
Consensus ranking of factors affecting IT-supported ITT

Factors	Focus group sessions				Classification of the factors
	FG1	FG2	FG3	FG4	
1. Appropriate and tested technology (transferred tech.) package that fulfills both the recipient and the market requirements	x	x	x	x	Micro-factor
2. Adequate financial resources	x	x	x	x	Micro-factor
3. Appropriate and adequate technical experts, technical support staff, and management people from all sides with clear roles and tasks	x	x	x	x	Micro-factor
4. Appropriate and adequate physical resources (e.g. computer hardware, software, manuals, machinery, equipment, etc.)	x	x	x	x	Micro-factor
5. Adequate training and training materials	x	x	x	x	Micro-factor
6. Appropriate and agreed upon specifications of IS	x	x	x	x	Micro-factor
7. Standard IT tools	x	x	x	x	Micro-factor
8. Effective international coordination	x	x	x	x	Micro-factor
9. Open, intensive, and effective communication between the key personnel of all parties	x	x	x	x	Micro-factor
10. Reliable IT, telecommunications, and other infrastructures	x	x	x	x	Telecommunications and IT industry level factors
11. Proactive leadership and management support, and high commitment from all parties including their top managements and personnel	x	x	x	x	Micro-factor
12. Experience with similar project implementation	x	x	x	x	Micro-factor
13. Competent project managers	x	x	x	x	Micro-factor
14. Effective control and risk management	x	x	x	x	Micro-factor
15. Motivating the project participants	x	x	x	x	Micro-factor
16. Proficient in language	x	x	x	x	Macro-factor
17. Functioning regulatory framework	x	x	x	x	Macro-factor
18. Availability of well-trained employees		x			Macro-factor
19. Positive attitude towards learning	x	x			Macro-factor

emphasis on micro-level factors but none of the micro-level factors ranked high in Table 2 are similar to the traditional DOI factors.

We checked the sensitivity of the ranking results with other methods developed for analyzing ordinal scale of measures. They give the same consensus ranking except for the ambiguities that it cannot resolve. Hence our results are not highly sensitive to the details of the mathematical method used.

6.2. How ITT success is improved?

We categorized the success factors in the following groups: (a) micro, (b) telecommunications and industry, (c) macro, and (d) international level factors. In the following we discuss in more detail how each of these groups affects ITT success.

6.2.1. Micro-level factors

Characteristics of an innovation: the following were important.

(a) *Appropriate and agreed upon specifications of IS* (ranked 6 in Table 2). All the investigated companies agreed upon the significance of specifications of IS for the technology recipients' organizations. It helped them to speed up the development and implementation of IS in recipients' organizations. It also helped to avoid unnecessary waste of time that commonly occurs due to changes of IS specifications by the people of the receiving organizations.
(b) *Standard IT tools* (ranked 7 in Table 2). All investigated suppliers implemented their company specific standard IT tools in the technology receiving organizations. These were proven IT tools that had already been implemented in several countries. The IT tools made the technology transfer quicker by improving the transfer process and enhancing the performance of the receiving organizations.
(c) *Appropriate and tested technology package that fulfills both the recipient and the market requirements* (ranked 1 in Table 2). The investigated companies transferred tested technology package that is appropriate at the recipients' sites. The technology package needs to fulfill requirements for both the recipient and the market.

Characteristics of a company: the following company level characteristics were important.

(a) *Resources and experience* (ranked 2, 3, 4 & 12 in Table 2). Interview data revealed that all the technology supplying companies had adequate financial resources. The companies also had appropriate IT people like systems development experts, engineers, and other staff who provide technical support to IT users. The companies had adequate operational as well as managerial knowledge and skilled people. The companies also had adequate hardware, software, manuals, machinery, equipment, etc., assisting the implementation of IT-supported ITT. Interview data also reveals that technology suppliers had already implemented the same standard engineering tools in several developing countries and emerging markets.
(b) *Leadership and management support* (ranked 11 & 13 in Table 2). Interviewees indicated that the top management of all the investigated companies provided effective support in the implementation of IT and the execution of IT-supported ITT. Also the project leaders, who supervised the implementation of IT and the execution of IT-supported ITT, were all competent. Most of the investigated companies mentioned that they relied on IT project leaders to impress and maintain a good relationship with the IT vendors in developing countries and emerging markets.
(c) *Training and training materials* (ranked 5 in Table 2). All the investigated companies provided intensive training for the technology recipient employees, enabling them to use the IT tools and transferred technologies. They also delivered adequate training material.
(d) *International coordination* (ranked 8 in Table 2). All investigated companies stated that for IT implementation and technology transfer, it is important to work with all major partners. For this it is necessary to have effective international coordination supported by various mechanisms, such as (a) preparing a project plan, making it available on the Web, and distributing electronically to everybody in the project, (b) giving clear responsibilities and tasks to key people in all sites, and (c) selecting and employing a coordinator at each site in different countries and giving them the responsibilities.
(e) *Open, intensive, and effective communication between the key personnel of all parties* (ranked 9 in Table 2). All of the investigated companies stated that for both IT implementation and technology transfer open, intensive, and effective communication between the personnel in all the phases of technology transfer is important. It improves understanding, builds trust, and assists in facilitating effective technology transfer.
(f) *Control and risk management* (ranked 14 in Table 2). IT implementation and transfer in a foreign country is risky. Therefore, effective control and risk management are important for the successful IT implementation and technology transfer. Yet, only one company put significant emphasis on risk management aspects of the IT project, mainly due to the large size of the IT project. Organizational structure and controls are necessary to deal with problems and risks.
(g) *Motivating the project participants* (ranked 15 in Table 2). High motivation of all participants is important, as both IT implementation and technology transfer in a foreign country are very complex. The project managers and top management can improve motivation of the project participants by understanding their cultures, treating them respectfully, identifying their unique needs and preferences, providing salary and rewards fairly.

6.2.2. Industry level factors: telecommunications and IT (ranked 10 in Table 2)

A good telecommunications infrastructure and developed IT industry of the receiving countries are critical for effective IT-supported ITT. Ironically, in most of the cases telecommunications and IT industry of the technology receiving countries were underdeveloped. This had a negative influence.

6.2.3. Macro-level factors

(a) *Availability of well-trained employees* (ranked 18 in Table 2). Most of the technology receiving companies faced problems in their IT implementations due to the lack of ''various categories of skilled IT people''. The exception was India where one company had found all categories of skilled IT people to be available making the IT project implementation easier.
(b) *Functioning regulatory framework* (ranked 17 in Table 2). An effectively functioning regulatory framework is essential for the successful transfer as well as protection of the production and service technologies that have been transferred to technology recipients. However, it was not a major issue for the development and implementation of IT.
(c) Cultural factors:

Language (ranked 16 in Table 2). Most of the technology recipients had problems due to limited language skills in English. However, employees of the technology recipient in India were well-educated and proficient in English. Language skills of software users significantly influence the success of IT innovation.

Positive attitude towards learning (ranked 19 in Table 2). The employees of both the technology recipients in India and Thailand were interested in learning new skills. However, the employees of the technology recipients in Hungary and Malaysia exhibited a negative attitude.

6.2.4. International factors

6.2.4.1. Economic growth. All the focus groups stated that global economic growth is helpful for the success of IT-supported ITT. However, case companies were not sure of its relative importance with respect to other factors.

To conclude, some other factors positively influenced IT-supported ITT. However, as our main objective is to determine, evaluate, and analyze the important factors we have not included those factors. The case companies that saw our research results expressed similar opinions about the importance of different factors. They also agreed that ''appropriate and tested technology package that fulfills both the recipient and the market requirements'' is the most important factor. In short, the focus group analysis followed by deriving a consensus ranking, was able to find factors that have content and face validity to explain successful IT-supported ITT.

7. Conclusions and implications

Effective ITT is essential for many high-tech companies to survive. Most companies have tried to use IT but have not been able to use it effectively during the technology transfer process. An in-depth literature review suggests that almost no studies exist on the topic and no empirical research has been conducted on this area. Although, there are studies that have been conducted on technology transfer based on conventional methods and national contexts. Yet, in such contexts companies can be unaware of what key resources are required to successfully implement IT and execute ITT.

We used diffusion of innovation (DOI) theory as a framework to study the factors that affect the success of IT-supported ITT. The factor approach of DOI theory guided us to develop an extensive questionnaire guide to identify factors which were reviewed for their content and conceptual validity in focus group. The DOI theory was extended with macro-level factors and industry level factors, apart from its micro-level factors. Literature on conventional technology transfer was also used to tap into relevant factors. Based on this framework, a focus group study was made to analyze the content and face validity of these factors and to rank them. A weakness of using focus groups is that the results cannot be generalized easily to the population as a whole and we cannot provide causal inference. The order of factors may also vary in larger countries in different cultures. Recursive branch and bound technique was used to organize the set of ranked factors into a consensus ranking.

Ranking shows that several micro-level factors other than those identified in DOI are consistently highly ranked in consensus ranking. Telecommunications and IT industry level factors have also some significance. This proves the inadequacy of using DOI theory as a predictive theory to explain the success of IT adoption and use in ITT contexts. Our study also shows that telecommunications and IT industry level factors as well as macro-level factors should also be considered. We identified several new factors that are not present in earlier theories. By concentrating on these important success factors, we believe a company can enhance their probability of success while engaging in IT-supported ITT.

During our theoretical discussions we also considered adaptation theory. Adaptation theory states if the innovation is changed to fit a new environment, then there is a higher possibility that the innovation will be implemented and used successfully in the new environment [1,31]. Within a technology transfer context adaptation theory suggests that if the technology is adapted (changed) to suit new conditions at technology recipient's environment, then there is a higher possibility that the technology will be diffused effectively in the technology receiving company. We learnt with our case companies, that this was not the case in our studied case. In contrast the supplier company played a lead role in shaping and adapting the technology. These were all companies with unique technologies, which had developed company specific IT tools (like simulator, etc.) or used standard IT tools, which they implemented at the recipient sites. All of them transferred technology on a continuous basis. They sometimes made small adaptations to fit to the market and the recipient (see the first factor in Table 2). In addition, several other factors (such as, adequate financial resources, experience in ITT; reliable IT, telecommunications, and other infrastructures;

availability of various categories of skilled employees, functioning regulatory framework, etc.) played a critical role in successful IT-supported ITT.

The research findings provide a vivid picture of types of resources required in IT-supported ITT. By using the research, companies can facilitate successful IT-supported ITT project completion. Thereby effective technology transfer will help companies to survive in an increasingly intense competitive environment.

Appendix A. Ranking of success factors by recursive branch and bound method: a description

Let us designate ith factor in Table 1 by a_i, $i = 1, \ldots, n$, where n is number of factors. In our case, $n = 19$. Then we have 4 rankings ($\alpha_1, \alpha_2, \alpha_3, \alpha_4$) constructed from appropriate focus groups (FG1, FG2, FG3, FG4). The rankings are as follows:

α_1:
$a_3 \sim a_4 \sim a_5 \succ a_1 \sim a_7 \sim a_{11} \sim a_{14} \succ a_2 \sim a_6 \sim a_9 \sim a_{10} \sim a_{18} \succ a_8 \sim a_{12} \sim a_{13} \succ a_{16} \sim a_{19} \succ a_{17} \succ a_{15}$

α_2:
$a_3 \sim a_7 \succ a_4 \succ a_{11} \sim a_{14} \sim a_{16} \succ a_1 \sim a_2 \sim a_5 \sim a_9 \sim a_{10} \sim a_{15} \sim a_{18} \succ a_6 \sim a_8 \sim a_{12} \succ a_{13} \sim a_{19} \succ a_{17}$

α_3:
$a_3 \sim a_4 \sim a_5 \succ a_1 \sim a_7 \sim a_{10} \sim a_{14} \succ a_2 \sim a_8 \sim a_{18} \succ a_6 \sim a_9 \sim a_{11} \sim a_{12} \succ a_{13} \sim a_{16} \succ a_{19} \succ a_{15} \sim a_{17}$

α_4:
$a_3 \sim a_4 \sim a_5 \succ a_2 \succ a_1 \sim a_7 \sim a_8 \sim a_9 \sim a_{11} \sim a_{14} \sim a_{18} \succ a_6 \sim a_{12} \succ a_{10} \sim a_{13} \sim a_{16} \succ a_{19} \succ a_{15} \sim a_{17}$

Here "$\succ$" means "better", and "$\sim$" means "equivalent". Thus α_1 corresponds to FG1, α_2 corresponds to FG2, and so on. α_1 is a ranking that ranks a_3 (that corresponds to "appropriate and tested technology package that fulfills both the recipient and the market requirements") as equivalent to a_4 (that corresponds to "adequate financial resources"), as equivalent to a_5 (that corresponds to "appropriate and adequate technical experts, technical support staff, and management people from all sides with clear roles and tasks"), as greater than a_1 (that corresponds to "appropriate and agreed upon specifications of IS") and so on.

Our aim is to find a linear (strict) order β of the factors $a_1, \ldots, a_n$, which would be nearest to all the given rankings $\alpha_1, \ldots, \alpha_m$ (in our case $m = 4$). The ranking β will therefore be a consensus ranking. Determination of such a nearest ranking is possible due to measure of distance between pairs of rankings first introduced in Kemeny and Snell [14] and discussed in Bogart [4]. The distance function $d(\alpha,\alpha_k)$ between α and α_k is defined by formula

$$d(\alpha, \alpha_k) = \frac{1}{2}\sum_{i,j=1}^{n} |\rho_k(a_i, a_j) - \rho(a_i, a_j)| = \sum_{i<j} |\rho_k(a_i, a_j) - \rho(a_i, a_j)| \quad (1)$$

Here $k = 1, 2, \ldots, m$ and for our case $m = 4$. α is any arbitrary ranking.

By general convention

$$\rho_k(a_i, a_j) = \begin{cases} 1, & \text{if } a_i \succ a_j \\ 0, & \text{if } a_i \sim a_j \\ -1, & \text{if } a_i \prec a_j \end{cases} \quad (2)$$

ρ_k corresponds to α_k and ρ corresponds to an initial test ranking α which is a logical guess for β. β that we want to find will satisfy the following condition:

$$\beta = \arg\min_{\alpha} \sum_{k=1}^{m} d(\alpha, \alpha_k) \quad (3)$$

Which means we will start with an arbitrary ranking α and minimize with respect to α to arrive at β, which is a ranking such that the sum of its distances from the four given rankings is minimized. To do this minimization, we introduce the distance matrix. We have started with a test ranking (which is an initial arbitrary α) such that $\rho(a_i,a_j) = 1$, for all $i < j$. This basically means that the initial test ranking is α: $a_1 \succ a_2 \succ a_3 \succ, \ldots, \succ a_n$.

Consider two elements a_i,a_j in all the given rankings where $i < j$. The $(n \times n)$ distances matrix $R = [r_{ij}]$ is constructed on the basis of (2) and defined by formula

$$r_{ij} = \sum_{k=1}^{m} d_{ij}^k, \quad i, j = 1, \ldots, n \quad (4)$$

where $d_{ij}^k = |\rho_k(a_i, a_j) - \rho(a_i, a_j)|$ for $i < j$.

Thus

$$d_{ij}^k = \begin{cases} 0, & \text{if } a_i^k \succ a_j^k \\ 1, & \text{if } a_i^k \sim a_j^k \\ 2, & \text{if } a_i^k \prec a_j^k \end{cases}$$

This is so as we have assumed that $\rho(a_i,a_j) = 1$. Then from formula (2)

$$d_{ij}^k = \begin{cases} |1-1| = 0, & \text{if } a_i^k \succ a_j^k \\ |0-1| = 1, & \text{if } a_i^k \sim a_j^k \\ |-1-1| = 2, & \text{if } a_i^k \prec a_j^k \end{cases}$$

Here a_i^k obviously means a_i in kth ranking. Eq. (4) therefore defines the upper triangular elements of R. All diagonal elements will be 0 as is obvious from Eqs. (2) and (4). The elements in the lower triangle of R is obtained on replacing $\rho(a_i,a_j) = 1$ by $\rho(a_i,a_j) = -1$. It essentially means that we interchange the positions of a_i and a_j in the test rank α. For our particular problem, the distance matrix R constructed by the initial rankings has the following view:

$$\begin{bmatrix}
0 & 3 & 8 & 8 & 7 & 0 & 5 & 1 & 2 & 2 & 4 & 0 & 0 & 5 & 1 & 2 & 0 & 2 & 0 \\
5 & 0 & 8 & 8 & 7 & 1 & 6 & 1 & 2 & 4 & 4 & 0 & 0 & 6 & 1 & 2 & 0 & 3 & 0 \\
0 & 0 & 0 & 3 & 3 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 5 & 0 & 3 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 5 & 5 & 0 & 0 & 2 & 0 & 1 & 1 & 2 & 0 & 0 & 2 & 1 & 2 & 0 & 1 & 0 \\
8 & 7 & 8 & 8 & 8 & 0 & 8 & 5 & 6 & 5 & 7 & 3 & 0 & 8 & 2 & 2 & 0 & 7 & 0 \\
3 & 2 & 7 & 6 & 6 & 0 & 0 & 1 & 1 & 1 & 2 & 0 & 0 & 3 & 0 & 0 & 0 & 1 & 0 \\
7 & 7 & 8 & 8 & 8 & 3 & 7 & 0 & 5 & 6 & 5 & 2 & 1 & 7 & 2 & 2 & 0 & 6 & 0 \\
6 & 6 & 8 & 8 & 7 & 2 & 7 & 3 & 0 & 4 & 6 & 1 & 0 & 7 & 1 & 2 & 0 & 5 & 0 \\
6 & 4 & 8 & 8 & 7 & 3 & 7 & 2 & 4 & 0 & 6 & 2 & 1 & 7 & 1 & 3 & 0 & 4 & 0 \\
4 & 4 & 8 & 8 & 6 & 1 & 6 & 3 & 2 & 2 & 0 & 1 & 0 & 5 & 0 & 1 & 0 & 3 & 0 \\
8 & 8 & 8 & 8 & 8 & 5 & 8 & 6 & 7 & 6 & 7 & 0 & 1 & 8 & 2 & 2 & 0 & 8 & 0 \\
8 & 8 & 8 & 8 & 8 & 8 & 8 & 7 & 8 & 7 & 8 & 7 & 0 & 8 & 2 & 4 & 0 & 8 & 1 \\
3 & 2 & 8 & 8 & 6 & 0 & 5 & 1 & 1 & 1 & 3 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\
7 & 7 & 8 & 8 & 7 & 6 & 8 & 6 & 7 & 7 & 8 & 6 & 6 & 8 & 0 & 8 & 4 & 7 & 6 \\
6 & 6 & 8 & 8 & 6 & 6 & 8 & 6 & 6 & 5 & 7 & 6 & 4 & 7 & 0 & 0 & 0 & 6 & 1 \\
8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 4 & 8 & 0 & 8 & 8 \\
6 & 5 & 8 & 8 & 7 & 1 & 7 & 2 & 3 & 4 & 5 & 0 & 0 & 7 & 1 & 2 & 0 & 0 & 0 \\
8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 8 & 7 & 8 & 2 & 7 & 0 & 8 & 0
\end{bmatrix}$$

It is important to note that every interchange of two elements of the test ranking corresponds to interchanging some element r_{ij} by r_{ji}. Hence the problem defined in Eq. (3) corresponds to finding such a permutation of the test ranking elements such that sum of the elements in the upper triangle of R is the minimum. It can be proved that any arbitrary permutation of the test ranking elements can be obtained by interchanging two elements at a time and successively apply the operation many times. So the idea is to keep interchanging two elements of test ranking unless the sum of elements in the upper triangle of R reaches the minimum.

The space of solutions for this problem is large. Its cardinality is $n!$ and it is well known that this problem is NP-hard [37]. However, for reasonable size (up to $n \approx 30$) there are exact algorithms (see [13,25,26,37]). One of them, first proposed in Muravyov and Savolainen [25] and further modified in Muravyov et al. [26], is described in short below.

The input of the algorithm will be the distance matrix $R = [r_{ij}]$ and the output will be the optimal $T^* = \beta$ and the corresponding upper bound value of the distance function l^u. The sequence of the elements in the initial test ranking is represented by the first n natural numbers. A permutation of the sequence of elements of the test ranking is therefore represented by a permutation of the first n natural numbers $\mathbf{N_n} = \{1,2, \ldots, n\}$. The initial test ranking is such that $a_1 \succ a_2 \succ a_3 \succ, \cdots, \succ a_n$. So the set $\{1,2, \ldots, n\}$is a sort of obvious way to represent this initial test ranking. Subsequent test rankings will be obtained by permuting the elements of the initial test ranking. And hence, a permutation of the n natural numbers also is a sort of obvious way to represent the subsequent test rankings.

The algorithm of determining an optimal interchange of the distance matrix elements uses the *recursive branch and bound* technique [42] and works in the following way. First of all it calculates l^0 that is the minimal possible value (lower bound) for the overall distance l^u from β (or α) to all other given rankings. It can be found from the formula

$$l^0 := \sum_{i=1}^{n} \sum_{j=i+1}^{n} \min\{r_{ij}, r_{ji}\} \quad (5)$$

If the matrix R is *transitive*, then $r_{ik} \leq r_{ki}$ iff $r_{ij} \leq r_{ji}$ and $r_{jk} \leq r_{kj}$, $i \neq j \neq k = 1, \ldots, n$. It means that the test ranking is consistent. In accordance to Litvak [19], on finding the problem solution we will satisfy this transitive property and also $l^0 = l^u$.

One can build an appropriate algorithm based on this principle. We used C++ to develop a code. The code used by us has the following view:

$$l^0 := \sum_{i=1}^{n} \sum_{j=i+1}^{n} \min\{r_{ij}, r_{ji}\}; \quad l^u := \infty; \quad T_0^2 := \mathbf{N_n}; \ \text{[initialization]}$$

$$\mathbf{OSM}(1, 0);$$

$$\mathbf{procedure OSM}(k, l^1):$$

$$\mathbf{for}\ i = 0\ \mathbf{to}\ n-k+1\ \mathbf{do if}\ l^u \neq l^0\ \text{then}$$

$$\begin{cases} T_{k-1}^1 := \mathbf{N_n} \backslash T_{k-1}^2; \quad \text{[partition of } \mathbf{N_n} \text{ into } T_1 \text{ and } T_2] \\ T_k^1 := T_{k-1}^1 \cup \{t_k^1 | t_k^1 = t_i^2, \ t_i^2 \in T_{k-1}^2\}; \quad \text{[branching]} \\ l := l^1 + \sum_{j=1}^{n-k} r_{t_k^1 t_j^2} + \sum_{s=1}^{n-k} \sum_{j=s+1}^{n-k} \mathbf{min}\{r_{t_s^2 t_j^2}, r_{t_j^2 t_s^2}\} \text{ with } t_s^2, t_j^2 \neq t_k^1; \quad \text{[calculate the distance]} \\ \mathbf{if}\ l < l^u\ \mathbf{then} \begin{cases} \mathbf{if}\ k < n-1\ \mathbf{then OSM}(k+1, l^1 + \sum_{j=1}^{n-k} r_{t_k^1 t_j^2}); \\ \mathbf{else} \begin{cases} T^* := T_k^1; \quad \text{[remember the complete solution]} \\ l^u := l; \quad \text{[and its total distance]} \end{cases} \\ T_k^1 := T_k^1 \backslash t_k^1; \quad \text{[pruning]} \end{cases} \end{cases}$$

On applying this algorithm we obtain the consensus ranking shown in Table 2.

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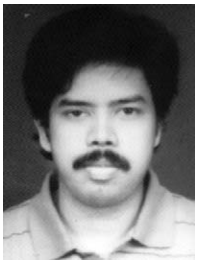

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