Routledge
Taylor & Francis Group

Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: www.tandfonline.com/journals/rcme20

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To cite this article: George Ofori (1994) Construction industry development: role of technology transfer, Construction Management and Economics, 12:5, 379-392, DOI: 10.1080/01446199400000049

To link to this article: https://doi.org/10.1080/01446199400000049

Construction Management and Economics (1994) **12**, 379–392

Construction industry development: role of technology transfer

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Received 10 April 1992; revised 15 February 1994

For several decades, transfer of technologies from industrialized countries has been viewed as a key to addressing the low level of technological development of developing countries. This paper considers technology transfer as a mechanism for improving construction industries in developing countries. It discusses the nature of technology and its development and the relevance of its transfer. It outlines differences between construction and other sectors and their implications for the development and transfer of construction technology. Results and problems of technology transfer are discussed and the experience of Singapore outlined. Possible action to improve upon the situation is suggested.

Keywords: Development, technology transfer, industrialization, Singapore.

Introduction

Need

Many writers stress the need to raise the level of technological development of the construction industries of developing countries (Ofori, 1990b). Figure 1 shows that, as a result of a series of vicious circles including inadequate technology, the industry fails to stimulate activity in other sectors of the economy.

Writers find it ironical that, for an activity dating back several centuries, construction in developing countries should rely on foreign techniques, materials and procedures (Abrams, 1964; Turin, 1973; UNCHS, 1985, 1990; Ofori, 1990b). This reliance drains scarce foreign exchange (Edmonds and Miles, 1984) and hinders development of local techniques and materials (Allal *et al.*, 1977; Bhalla and Edmonds, 1983). Many reasons for this reliance are outlined. The United Nations Centre for Human Settlements (UNCHS) (1990) suggests that available appropriate construction technologies are not employed because professionals lack proficiency in their use.

Structure of the paper

This paper first briefly reviews works on the nature of technology and its development and the role of technology transfer in the latter. It highlights the achievement and problems of technology transfer. It then considers construction technology transfer, especially that to contractors. The experience of Singapore in construction technology development is outlined. Measures for making construction technology transfer more effective are then highlighted.

Nature of technology

Technology may be defined as the application of the existing body of knowledge (science) to the production of goods and services. It embraces equipment, tools, techniques, materials, systems, processes, information, the goods and services produced and their use (Stewart, 1977; Streeten, 1991). Writers disagree on many of the definitions, causes, implications and effects of aspects of technology. However, there is broad consensus on many issues. For example, there is general agreement that technology is critical for development (Goulet, 1977).

The study of technology has become an established descriptive science. Van Wyck (1988) suggests that initial attempts outlined the evolution and future course of certain technologies. Later authors studied the general thrust of technologies, culminating in an organ-

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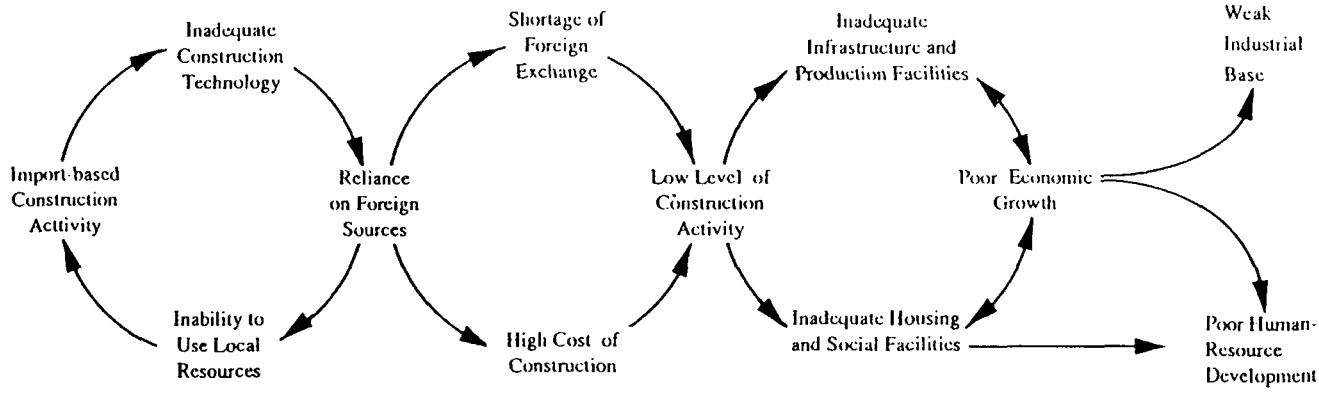

Figure 1 Consequences of inadequate construction technology in developing countries

ized field of study within which strands such as technological analysis and technometrics have emerged.

Various 'types' of technology are often distinguished. Goulet (1977) differentiates between 'modular' (core) technologies 'which are indispensable to the success of an entire process' (p. 178) and 'peripheral' (ancillary) ones which constitute the rest. Westphal *et al.* (1985) categorize technological capability into three broad areas: production (for operating productive facilities), investment (for expanding capacity and establishing new productive facilities) and innovation (for developing technologies).

Many aspects of technology may be considered to highlight its complexity. In the context of this paper, its linkage to social systems (Goulet, 1977; Galtung, 1979; Karatsu, 1990; Mtewa, 1990) is perhaps most relevant. UNIDO (1980) considers technology as a 'not neutral' (p. 3) entity, incorporating, reflecting and perpetuating value systems. This means that technology transfer implies the transfer of social structure. Moreover, Rosenberg and Frischak (1985) suggest that the technology any enterprise uses is specifically chosen and shaped by the company's learning experiences: this complicates the transfer process. Studies show that factors including differences in resources, wealth, religion, customs, climate, political system and trading conditions can hinder the transfer of technology (Jones and Gamser, 1987; Streeten, 1991).

Technology development

As the main aim of technology transfer is to effect technological development, it is pertinent to consider the latter briefly. Various writers discuss causes, effects, prerequisites and advantages and disadvantages of technological change (Bowley, 1966; Marx and Engels, 1970; Caldwell, 1972; Maitra, 1980; Podder, 1988). The general consensus may be outlined.

The pace of technological change differs from one country to another. It requires capital, appropriate socio-economic conditions, organizations which can take advantage of opportunities offered by new technology, a suitable physical infrastructure and a supportive culture. Technology can be an exogenous force with a will of its own, developing independently of the prevailing political, economic and social forces and has a major influence on these other forces. Not all technological change is welcome (Alfthan, 1985). However, new technologies are continually needed to ensure progress and to address mistakes resulting from previous ones (Sharif, 1983).

Trends of technological change often identified include (Van Wyck, 1988) increasing efficiency, i.e. ratio of output to input, increasing capacity, i.e. output per unit of time, increasing density, i.e. output per unit of space required in production, increasing accuracy, i.e. precision with which a given outcome is specified, increasing size range and increasing complexity. Podder (1988) suggests that faced with a set of technologies, an entrepreneur always chooses the most cost-effective which, given prevailing constraints, is usually the latest. However, Moore (1982) believed that firms seldom make the optimum choice owing to gaps in knowledge about technology and firms' tendency to be averse to risk and cautious about change. Given the wide range of possible choices and as change may arise from greater knowledge about and adaptation of existing technologies, change is not necessarily a progression towards the most modern computer-controlled capital-intensive process.

Technology development is different from normal investments by an organization: not every acquisition of new equipment involves technological change. Studies show that in industrialized countries, technological change has greater influence on economic growth than investment, although investment appears important in developing countries (Solow, 1957; Denison, 1967; Fraumeni and Jorgenson, 1980; Koppers *et al.*, 1991).

Table 1 Features of construction and their effects on technology and its transfer

Feature	Effects
Importance and large size of industry	Industry's products are essential for socio-economic development. Its improvement is vital. Large output offers the opportunity of transferring desirable technologies, but foreign firms may simply undertake major projects and usually do
Government a major client	Public-sector projects can be the basis for developing suitable technologies. They can be used to diffuse desirable construction and related technologies
Nature of demand	Demand for one-off items, and fluctuations in overall levels. Contractors' obtaining work by tender implies lack of continuity of use of technologies. Technologies transferred may not be subsequently used
Price determination	Contracts awarded via some form of tendering, based mainly on price. Special technical capability not always paramount among selection criteria
Location specificity of product	Potential for using construction to transfer technology and develop a technology culture in all parts of the country. Transportation an important component of project cost, giving 'local' contractors some competitive advantage
Wide range of technologies	Most technologies to be transferred to developing countries already in public domain. Thus, oligopoly or monopoly in technology (to be transferred) limited. 'Islands of technology' may emerge. In various sectors of the industry, technology development may take a different nature and path and involve different aspects. Generally, pace of development is slow
Government's involvement in process	Government regulates and administers industry and its activities. Statutes, regulations and codes influence technologies to be used. With appropriate policies, the government can play a crucial role in construction technology development
Organization of process	Contractor often has limited say in choice of technology. Knowledge of nature and management of technologies should be widely disseminated within industry, to contractors, designers and cost consultants

Construction technology and its development

Construction technology

Construction technology embraces the materials, plant and equipment, organizations, procedures and information systems used in planning, designing, constructing, maintaining, repairing, altering and demolishing buildings and infrastructure. Construction technology development involves both imaginative solutions to specified problems and the development of alternatives to existing materials, methods and so on (Madewell, 1986). Table 1 highlights features of construction and their implications for construction technology development. Some writers consider as the key to construction technology development, a particular set of systems such as standardization and industrialized construction (United Nations, 1959, 1974) and computer applications and robotization (CIB, 1989). However, owing to the variety of circumstances and objectives, such deterministic approaches cannot be universally appropriate.

There is a common perception that construction everywhere lags behind other sectors in the level and pace of technological development (Business Roundtable, 1983; Nam and Tatum, 1988). Some writers, who dispute this, question the accuracy of the usual measures of construction productivity (Rosefielde and Mills, 1979; Bowley and Scriver, 1986); others highlight progress made in construction technology (Jepson, 1987; Chow, 1990).

Obstacles to construction technology development often cited include the conservatism of construction practitioners (Bowley, 1966; Groak and Ive, 1986), the fragmented nature of the industry (Ofori, 1990b) and the craft-based nature of its work and the influence of unions (Bowley, 1966; Tatum, 1989). In developing countries, the influence of regulations is most often highlighted (UNCHS, 1985; Barclay, 1987; Spence, 1987). Nam and Tatum (1988) highlight features of construction hindering the industry's technological development. However, Kangari and Halpin (1989) and Chow (1990) observe that some sectors sharing characteristics with construction such as aircraft manufacturing are technologically sophisticated. Groak and Ive (1986) stress that, rather than being passive and at the mercy of external forces, construction enterprises can control aspects of their work. That some firms enhance their competitiveness through technology (Hasegawa, 1988; Rashid, 1990) indicates its relevance.

The technological development of construction industries of developing countries is low, both in

comparison with their counterparts in industrialized countries and considering their present and future tasks. This is perhaps most evident in their failure to use the countries' resources (Fig. 1) leading to huge volumes of unmet needs and high construction costs. While inadequate technology is not the only, nor the main problem facing these industries, upgrading their level of technological development can help improve their performance (Ofori, 1991).

Construction technology development

Several factors give impetus to technology development in construction. First, changes in the nature of the buildings and works demanded by clients result from economic, social and technological change (market pull) (Ofori, 1990b). Second, increasing scientific and technical knowledge within or outside the industry make new materials, equipment and methods available for application (science-technology push) (CIB, 1989). Third, shortage or increasing cost of a resource influences change (necessity leading to innovation) (Ofori, 1990b). Fourth, construction companies seek to enhance their competitiveness through innovation (intraindustry competition) (Hasegawa, 1988; Tatum, 1989). Fifth, professional institutions and trade associations attempt to extend the scope of activities of their members (Brandon *et al.*, 1988). Finally, the government endeavours to upgrade the construction industry (CIDB, 1989).

Respondents to a survey in Singapore ranked benefits they obtained from the application of new construction technologies as follows (Ofori, 1990a): faster project completion, improvement in quality of workmanship, reduction in labour requirement and lower overall operating cost.

Technological situation of developing countries

General situation

Studies (UNIDO, 1980; UNCTAD, 1990a; Stewart, 1991) show that, by any of the proxies used to measure a country's technological development, number of research and development (R&D) personnel, aggregate R&D expenditure, volume of manufactured exports, share of high-technology services and number of international patents owned, there are great and widening disparities between industrialized and developing countries. The appropriateness of some of these measures may be disputed. For example, a country's volume of exports is influenced by many factors including access to markets. However, developing countries are technologically dependent on industrialized ones; they import elements of a wide range of technologies. Construction is closely related to many sectors of the economy (Rosefielde and Mills, 1979; Hillebrandt, 1984; Ofori, 1990b). Thus, it would be disproportionately affected by technological inadequacies in the nation.

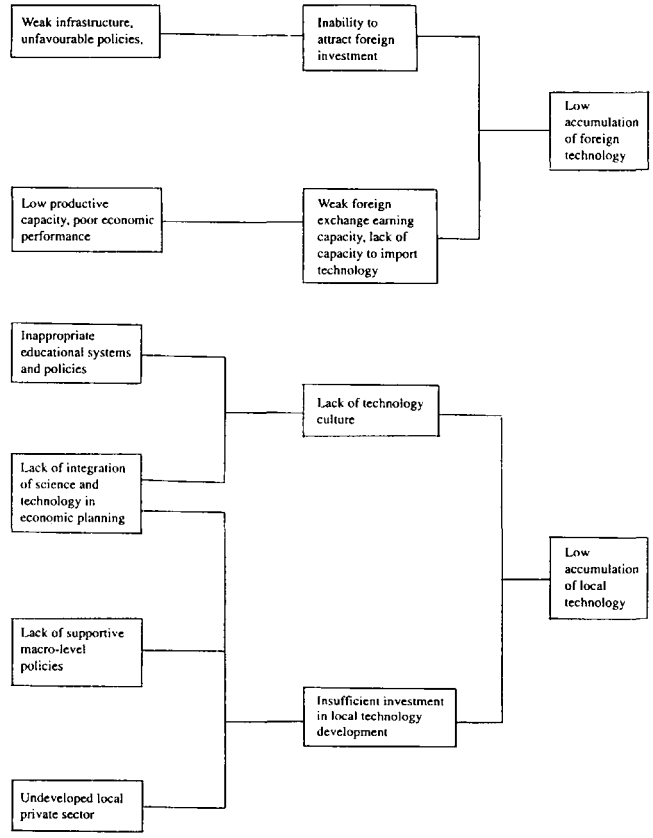

Figure 2 Factors contributing to low level of technology development

As shown in Fig. 2, the technological weakness of developing countries is attributable to many factors with varying influences in individual countries (UNIDO, 1980; Choi, 1983; UNCTAD, 1990a). Figure 3 shows in detail the implications, for technology development, of inappropriate macro-level policies.

Technology development initiatives

Different methods have been adopted, over time, to promote, stimulate and assist technology development in developing countries (Sharif, 1983; Stewart *et al.*, 1989). These include pursuit of national self-reliance, embracing attempts to substitute for imports and efforts to develop appropriate technologies (Schumacher, 1973; McRobie, 1981). Another approach is the transfer of technologies from industrialized countries. The final relevant path is technical cooperation among developing countries (TCDC) (UNIDO, 1980).

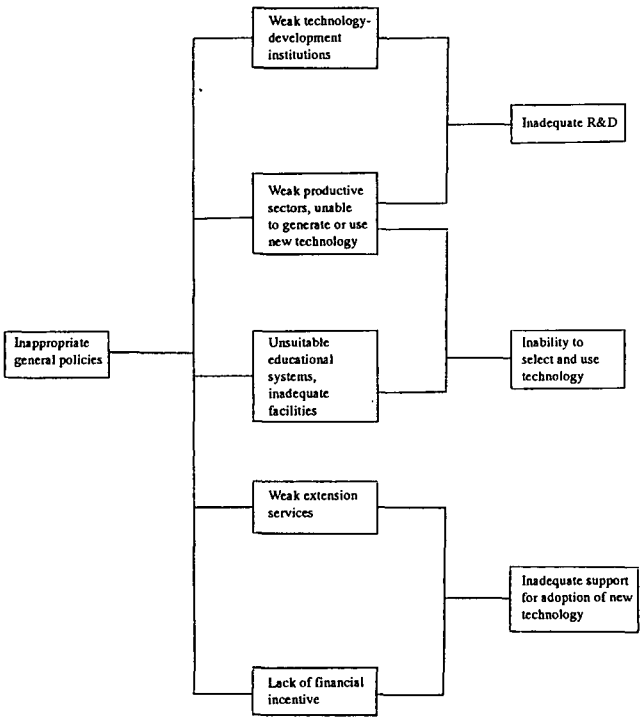

Figure 3 Effect of inappropriate general policies on technology development

Many developing countries have formulated technology policies through which they aim to obtain all relevant technologies, optimize use of these technologies, create a technology culture, build up their own technology and adopt suitable regulations on technology transfer (Goulet, 1977; Choi, 1983; Segal, 1987; Rosenberg, 1990).

Current issues

The rate of change of technology is increasing apace, having an impact on economic and social progress, competitiveness of countries and international relations (Economic and Social Council for Asia and the Pacific, 1993). Streeten (1991) suggests that emerging technologies are relevant to developing countries since they economize in managerial, supervisory and administrative skills which they lack. Globalization has become a key corporate operating strategy (Ohmae, 1990), fuelling competition among countries to attract productive enterprises. Jasic (1993) considers the effect of globalization on technology transfer. Transnational companies are becoming increasingly concerned with genuine international cooperation (Abbott, 1985a; Oyama, 1993).

In many developing countries, foreign construction enterprises are undertaking major projects as the infrastructure is being rehabilitated and extended under economic restructuring programmes. Many international contractors use technology transfer as a competitive tool (Abbott, 1985a; Rashid, 1990). The Japan International Development Organization (JAIDO), sponsored by major private enterprises and established in 1989, provides capital, managerial and technological support to entice Japanese companies to developing countries and encourage development of local enterprise through joint ventures (Saphir and Nishimura, 1993). One of JAIDO's current projects is a US$254 million high-technology building in Bangkok, Thailand.

With more effective dissemination of available technologies, developing countries are more aware of appropriate technologies and their potential. For example, a UNCHS (1988) compendium of local building materials outlines raw-material winning and processing methods, production techniques, equipment required and their possible sources and ways of improving the technology and the products. Some foreign companies specialize in appropriate materials and techniques which they are transferring to developing countries (McRobie, 1981; UNCHS, 1988). There is also greater cooperation and networking among developing countries (UNCHS, 1990). Finally, concern with the environment is stimulating reappraisal of technologies (Ofori, 1992).

It appears developing countries have not benefited fully from these developments. For example, studies show that, despite liberalization of investment-related policies in many developing countries, foreign direct investment there diminished during the 1980s (UNCTAD, 1990b). Nevertheless, in the light of these trends, technology transfer offers scope for improving construction industries in developing countries and merits further consideration.

Technology transfer

Nature and sources

Technology may be transferred between persons, between parts of an organization, between organizations, from a research centre or educational institution to industry and between countries. In its most common usage, technology transfer refers to formal and direct arrangements based on an agreement between a buyer and a seller or a non-commercial arrangement between a donor and a beneficiary. Technology transfer is not providing the receivers with solutions to specific problems (Wallender, 1979). UNCTAD (1990a) and Andrews (1992) suggest that effective transfer occurs when technology is requested, transmitted, received, understood, applied, diffused widely and improved.

This paper concentrates on transfer of technologies between countries: the process is illustrated in Fig. 4. This occurs in different ways, as shown in Fig. 5

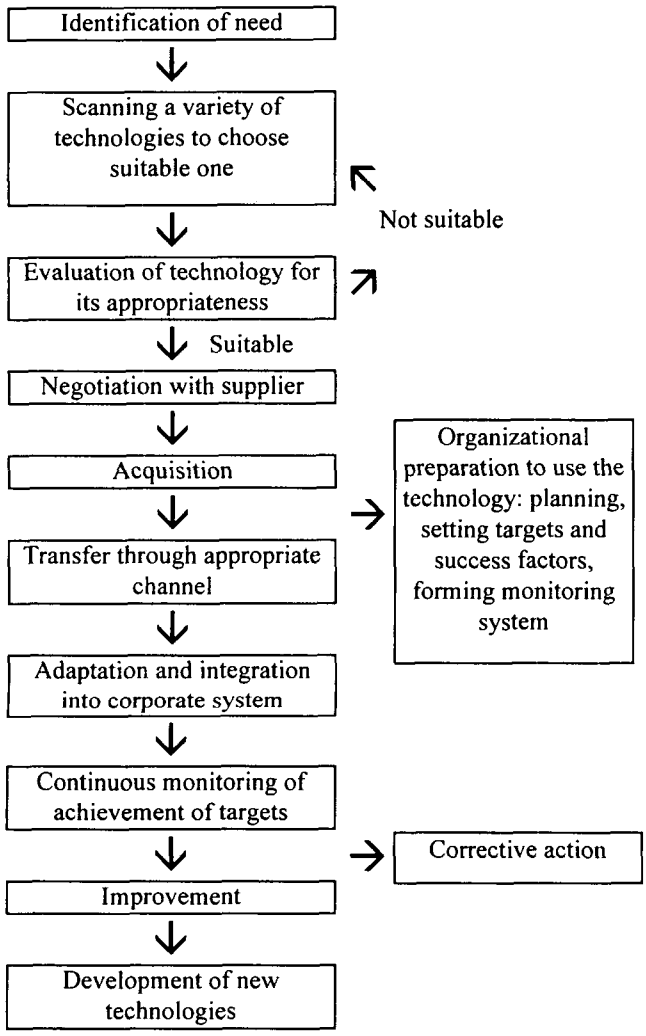

Figure 4 Technology transfer process

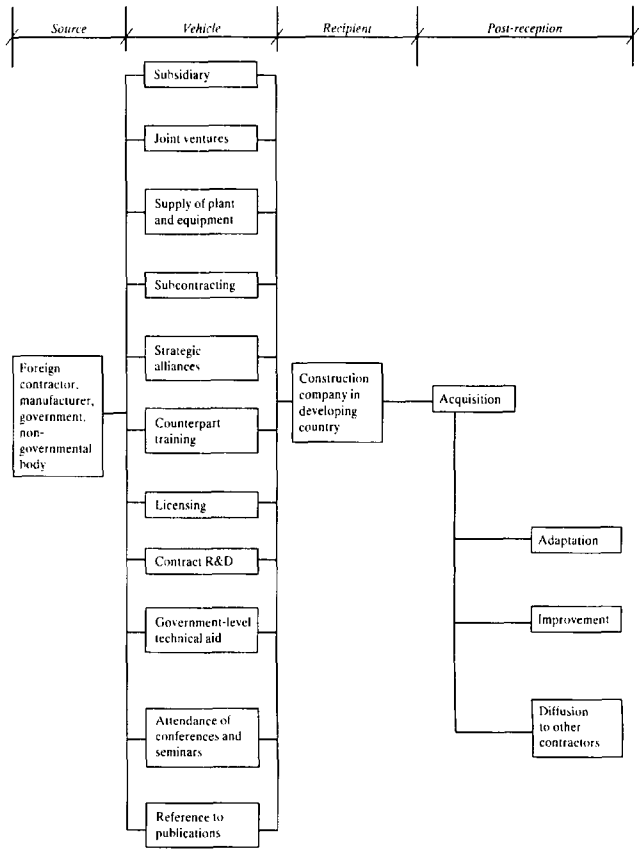

Figure 5 Construction technology transfer vehicles

(OECD, 1981; Choi, 1983). Stewart (1991) suggests that dominant vehicles of technology transfer have changed over time: the control of suppliers has reduced as developing countries have pressed for more liberal terms.

Previous studies and potential

Interest in technology transfer started in the early 1960s. Gruber and Marquis (1969) observed that it had not been adequately studied, considering its importance. Since then, much research has been undertaken. Sagafi-Nejad *et al.* (1981) highlighted main issues debated in the 1970s: importance of technology to development, who controls technology after its transfer, alleged restrictive practices of suppliers, prices paid for technology, role of government and conflict resolution and dispute settlement. These had resulted in 'myriad control systems, policies and instruments . . . at the corporate, national, regional and international levels to influence the quality and quantity of technology flows' (p. xiii). Many of these issues are considered below.

Early writers considered technology transfer to be an affordable short-cut to development (Emmanuel, 1982). If successful, it would enable the recipient country to substitute for imports, stimulate exports and improve economic efficiency (Samli, 1985). Suppliers could also extend the lives of their technologies, spread R&D costs (Stewart, 1991) and penetrate new markets (Cockburn, 1970; Abbott, 1985a).

Stewart (1991) views the wide range of technologies available for use by developing countries both an opportunity and a threat, the latter owing to the high costs involved: high price for technology transferred, foreign ownership of many of the countries' industries and possible unbalanced development and environmental degradation. Thus, some writers rightly stress the need for technologies transferred to be appropriate (Stewart, 1977) and highlight the importance of key prerequisites including appropriate transfer vehicles (Jones and Gamser, 1987), governmental commitment and macro-level policies (Stewart, 1991).

Government's role

Policies on technology transfer seek to encourage, guide and control it (UNCTAD, 1981; United Nations, 1983). Mexico's laws and regulations on technologies allowed and conditions of their transfer are often referred to (Goulet, 1977; Stewart, 1979). Stewart (1991) suggests that governments have to decide 'how far to intervene and where' (p. 60). Goulet (1977) advises developing countries to seek to strengthen their infrastructure, improve their negotiating positions and skills, pursue technological exports while seeking selective imports, promote concerted action among their technology-transfer actors and seek support from international agencies. Prebisch (1970) urged Latin American countries to pursue a timely, energetic and enlightened policy of international cooperation.

However, excessive regulation may be counter-productive. Behrman (1974) rightly refers to the need to ensure that regulation does not merely control restrictive and undesirable practices, but positively fosters the achievement of desired objectives.

Results

Progress

Technology transfer has had different results in various contexts and sectors of the economy. It helped close the 'technological gap' between the US and Europe in the 1960s and 1970s (Pavitt, 1985). It also contributed to the rapid progress made in newly industrializing economies (OECD, 1981; Choi, 1983). Japan's early industrial success is attributed to transfer based on imitation (Oppenheim, 1991). New strains of crops and production methods have led to a 'green revolution' in many developing nations. Some success has also been realized in manufacturing using mainstream technology such as in textiles. Studies show that technology transfer is not a unilinear North–South flow (Althuis and Vervuurt, 1983). Lall (1982) cites organizations in Argentina, Brazil, India and Mexico which are competitive in exporting a range of technologies, mainly, but not solely, to other developing countries.

Despite these results, the high expectations of technology transfer to developing countries have not been realized. This indicates the naivety of earlier expectations and complexity of the transfer process (Althuis and Vervuurt, 1983; Rosenberg and Frischtak, 1985).

Problems

Imported technologies are generally inappropriate to developing countries in terms of the products for which they are designed, their volume of production and their capital-intensive, import-dependent, high energy consuming and sometimes polluting nature (Stewart, 1977; Sharif, 1983; Streeten, 1991). The productivity of technologies transferred is often below its level at their source; they have required protection in order to be viable (Spence, 1987; Stewart, 1991). Many writers observe that transnational corporations operating in developing countries contribute little towards the countries' technological development (UNIDO, 1980; Sharif, 1983; Saphir and Nishimura, 1993). Their technological choices and modes of operation seldom reflect local economic and social requirements.

Technology transfer is characterized by differences in bargaining power between buyers and (often oligopolistic) sellers (Steward, 1991; Streeten, 1991). Buyers lack the capacity to determine their needs, negotiate good terms for the transfer and monitor transferred technologies. Sellers often place restrictions on transferred technologies, for example, forbidding the export of goods produced with the technology. Buyers are suspicious and dissatisfied (Patel, 1980).

Technology transfer has become a politically-sensitive international issue as discussed above (Sagafi-Nejad *et al.*, 1981; van der Horst, 1983; Oldham, 1987). Some writers brand it a myth (Ernst, 1983): it has increased international inequalities because source corporations are selective in their choice of countries to invest in, partners to cooperate with or firms to sell technologies to. However, suppliers suggest that the complex and dynamic nature of technology transfer should be recognized: they should not be expected to part cheaply with a valuable resource, that is, technology (De Cubas, 1974; Bradbury, 1978). Indeed, suppliers face problems including exposure to political and economic instability, inadequate policy framework, insufficient protection of property rights, political pressures at home and in host countries and inadequate corporate mechanisms in recipients.

Measuring technology transfer

The volume of technology transfer is often measured in monetary terms considering technology purchases by the recipient country (Lall, 1982; Rosenberg and Frischtak, 1985). However, this would omit indirect transfer channels such as reference to publications. Moreover, even a full measure of the volume of technology transfer would not indicate its effectiveness.

The effectiveness of technology transfer is difficult to measure owing to the many influencing factors and (competing) actors with different interests (Erdilek and Rapoport, 1985). Gruber and Marquis (1969) suggest that the magnitude of technology transfer is a function of the source, nature of technology, channels of transfer and features of recipients. Similarly, Baranson (1976) observes that the time and resources required to transfer technology depend on: the technology, mode of transfer, absorptive capabilities of recipient enterprises,

capabilities and motivation of suppliers and technology gap between supplier and recipient. Ono (1976) categorizes these into: recipients' need and spirit for technological progress ('pull' factors), suppliers' need for technology transfer ('push' factors), role of producers' associations and role of government.

Construction technology transfer

Rationale and forms

Owing to the pressing and varied developmental needs of emergent countries, they have to import some construction capacity (Drewer, 1980). Unlike industrialized countries, their construction industries cannot advance technologically as they meet progressively more complex local demands and benefit from technological developments in other sectors (Ofori, 1990b). Technology transfer from foreign companies undertaking the more complex projects and through other vehicles, would help bridge the gap.

Whereas assembly techniques are often emphasized, the transfer of other aspects of construction technology is important (Wesley, 1987). For example, while site techniques may be project specific, managerial expertise can be applied widely over a long period and would enable effective use of all technologies. Thus, Kirpich (1987) and Rosenberg (1990) suggest that priority should be given to the improvement of managerial capability in developing countries.

Vehicles

Construction technology may be transferred through joint ventures between foreign and local companies, which may either be project specific or of a longer term nature. From previous experience, agreements on purchase of equipment now often provide for training, spare parts and/or technical services (Turin, 1973; Ofori, 1990b). In the appropriate construction technology field, plant and equipment are often supplied with the disembodied technology. For example, a UK company provides brick-making equipment in kit form, with information on how it may be replicated (McRobie, 1981).

Another important construction technology transfer vehicle is counterpart training ('liaison engineering') (Uko, 1987). Training packages are often included by developing-country governments and/or donors in contracts involving foreign companies. Governmental level arrangements may involve a medium-term programme of technical assistance. For example, in Tanzania, a national health facilities programme funded by Sweden involved expertise from the donor in the design, supervision and monitoring of construction of low-cost health buildings. Rural development programmes sometimes incorporate technology transfer in materials production and in construction. In Kenya's rural roads programme, residents of villages along the route were trained to maintain the roads (De Veen, 1980). A similar scheme in Ghana is transferring labour-intensive technology to small contractors (Department of Feeder Roads, 1990). Finally, local companies learn by observing operations of their foreign counterparts, as has been successfully done in Singapore (discussed below).

Results of previous efforts

Construction technology transfer is widely supported by public-sector clients in developing countries and lending agencies, but appears more problematic than transfer in other sectors (Cockburn, 1970; Abbott, 1985b; Carrillo, 1993) (Table 1). Foreign firms are unwilling to nurture potential competitors, especially in a competitive world market where contractors from countries such as Brazil, China, India, South Korea feature prominently (Strassman and Wells, 1988). Construction technology transferers may face extra costs, project delays and managerial complexity, over the difficult and risky business of contracting overseas. Moreover, the uniqueness of construction projects makes it difficult for trained local personnel to utilize acquired knowledge (Uko, 1987) and hinders learning from experience in technology transfer (Table 1).

The joint venture appears the most widely preferred vehicle of construction technology transfer. The World Bank favours it, but prefers voluntary arrangements to mandatory ones specified by some countries as a condition to the award of major contracts (Cox, 1982). The joint venture is not a universally successful transfer vehicle. It is difficult to match the foreign partner's commitment to technology transfer with its suitability for the project and to monitor transfer (Andrews, 1984; Chow, 1985). In a cross-cultural situation where there is potential for conflict, effort required to resolve or prevent disputes between partners would leave less time for technology transfer. Despite these difficulties, some foreign contractors utilize technology transfer, mainly through joint ventures, to enter and stay in markets (Abbott, 1985b; Strassman and Wells, 1988).

A case study: construction technology transfer in Singapore

The experience of Singapore illustrates the merits of a comprehensive approach to construction technology development and the role technology transfer can play in it.

Government's technology development schemes

Measures have been adopted to promote, stimulate and support the technological development of the construction industry of Singapore (Chow, 1990; Ofori, 1990a; Low and Tan, 1993). Under economy-wide and specially dedicated schemes, contractors are offered loans and tax concessions to acquire plant and equipment and grants for R&D. Innovative designers and contractors receive annual national awards.

The Construction Industry Development Board (CIDB) offers support (including advisory services, manuals and seminars) for industry-wide application of 'strategic' technologies (including, over time, curtain walling, pipe jacking, prefabrication, information technology and intelligent buildings). Major public-sector clients demonstrate the use of certain techniques and require contractors to use particular equipment. A state-owned construction company demonstrates the viability and best use of advanced technology.

Technology transfer

The government actively promoted technology transfer through joint ventures between local contractors and foreign ones. Under the Preferential Margin Scheme (PMS) introduced in 1980, local companies and joint ventures with at least 25% net local equity participation were offered a preferential margin of up to 5% of the bid or S$5 million, in public-sector tenders. Successful applicants were required to submit, to the CIDB, a programme for (and periodic reports on) transferring technologies to their Singaporean personnel. Companies failing to achieve the targets might have to refund the preference offered. Technologies to be transferred were specified in the project's general conditions of contract. The Mass Rapid Transit Corporation, administering the US$3 billion railway system, established a technology-transfer monitoring department. In 1990, observing that the PMS had served its purpose, the government replaced it with a bidding-preference scheme linked to quality of work. Thus, the phase of government-supported technology transfer in construction has passed in Singapore.

Comments on the benefits of joint ventures to the Singapore construction industry were initially adverse (*The Contractor*, 1985). Tan (1989) evaluated technology transfer programmes of 12 joint-venture firms. Most respondents formed a joint venture mainly to benefit from the PMS. Local firms hoped joint ventures would help them to overcome their greatest weakness: lack of an efficient management system. Acquiring knowledge of advanced construction methods, such as tunnelling, was not a priority, possibly because of high capital costs and infrequent usage. Few joint-venture agreements elaborated on technology transfer. Training programmes were unstructured and poorly resourced. Most local partners played minor roles in operations of joint ventures. However, most respondents claimed they had acquired the expertise for specialized work. Tan's (1989) findings are similar to the results of a UK study by Carrillo (1993).

Joint foreign-local ventures (mainly to pool expertise and resources) remain common in Singapore. Despite the usually loose arrangement, anecdotal evidence shows that there is acrimony among partners of many joint ventures, some of which have broken up prematurely, although some are over 15 years old. This highlights the difficulties with joint ventures. The predominance of subcontracting in Singapore also helps transfer of technologies from foreign companies and diffusion within the industry.

Results

In approximately a decade of active technology development, Singapore's construction industry has been transformed. The industry is exploiting the buoyant regional construction market – the value of contracts secured overseas by Singapore contractors grew 7-fold between 1984 and 1992 (Ofori, 1994). While it is difficult to isolate the contribution of technology transfer to this improvement, local enterprises report that they have emulated aspects of foreign enterprises' operations, especially their systematic project and corporate management. The market share of foreign companies has declined (Ofori, 1994).

While technology transfer appears to have worked, the Singapore construction industry still has some weaknesses (Ofori, 1994). Its productivity is considered low (CIDB, 1993). This indicates that construction technology development is a long-term process.

Synthesis

Six major points can be distilled from works on technology transfer and the foregoing discussion. First, technology development requires a country-specific approach with a sound overall policy infrastructure within which technology transfer should be planned and continually monitored. Second, technology transfer should be part, not the whole, of technology development programmes. Third, technologies to be transferred should be selected with regard to their potential for supporting and promoting technological self-reliance and appropriateness to the recipients' needs and resources. Wherever possible, recipients should be involved in the choice. Fourth, successful technology transfer depends on the buyer's ability to absorb, adapt, apply, master and integrate the transferred technology into its existing systems, improve upon it and use it to

upgrade other technologies. Fifth, choice of transfer mode is crucial. Complexity of the technology should be matched with the background of target recipients and necessary training and/or technical advice provided. Finally, the supplier and recipient(s) of each technology should be carefully selected. The former should be committed to transfer and the latter should be able to benefit from it: both should be prepared to invest in the process.

These 'points' are adapted and extended below to outline possible courses for action in using technology transfer to improve the construction industries of developing countries.

The future

Policies and their administration

Construction and national technology development

Construction technology development should be pursued under an integrated programme forming part of overall national development policy. It should be centrally guided and monitored. Indirect ways of transfer should be recognized and stimulated. Policies and schemes should be reviewed as the industry develops.

The national programme for construction technology development should pursue the various possible approaches – self-reliance, import substitution, development and use of appropriate technologies and technology transfer – together. Each may be relevant to a specific part of the industry. The approach to transfer in each part may also differ, as shown in Table 2, using the construction industry matrix proposed by Ofori (1990). Various technologies would require different considerations as to the most suitable source, effective transfer mechanism, form of agreement, administrative system and support services.

Technology transfer

Construction technology development and technology transfer should be planned and coordinated by a central body (either a separate agency or a unit in the ministry responsible for construction). Policy and programme formulation would benefit from the experience of newly industrializing economies (such as Singapore) and other developing countries (such as Brazil) and other sectors of the economy such as agriculture.

Policies on construction technology transfer should embrace all its stages (Fig. 4) and be integrated with those on construction technology development, with overall construction industry policies and with macro-level policies. Policies imposing conditions on commercial relationships merit careful consideration (as to potential benefits, negative influences and implementation difficulties). For example, making formation of joint ventures mandatory for all foreign contractors might result in 'joint ventures of convenience'. Protection of 'infant' industries might also lead to feather-bedding of local enterprises and shielding of inefficiency, unless it targets parts of the industry which would benefit from such protection.

Table 2 Construction technology transfer to various sectors of the industry

Part of industry	Features of technologies and suitable vehicle
International large	Technologies likely to be infrequently used. Management systems most relevant. Transfer by observation, seminars introducing 'strategic' technologies and subcontracting of work involving less advanced techniques. Development of skills for maintaining the completed facility is very important
Conventional large	Many technologies would be relevant. Selection of 'strategic' technologies and transfer through joint ventures with *large* local companies. Counterpart training should be stressed. Measures are required to prevent joint ventures of convenience. Public sector projects can be used for transfer
Conventional medium/small	Many possible approaches. Diffusion of technologies from large local companies in conventional large sector and from research centres. Reference to literature and attendance at conferences. TCDC is relevant. Transfer of appropriate technologies from non-governmental and specialist commercial organizations abroad is also relevant
Self-help	Appropriate technologies can be transferred to local communities for creation and maintenance of basic buildings and infrastructure. Transfer through demonstration and training
Monetary-traditional	Improved materials and related techniques to be transferred to itinerant tradespersons through extension programmes involving research centres
Subsistence	Transfer of improved materials and related techniques to rural householders through mass media and exhibitions

Attributes of both recipient and supplier of the technology should be considered. The supplier should be given an incentive for the transfer. The recipient may require technical assistance to improve and diffuse the technology and opportunities to use the acquired knowledge. For example, technology transfer could be linked to a tendering preference scheme, perhaps, for a period.

Choice of technology and transfer mechanisms

The whole technological continuum – from the most advanced to the most basic – should be considered. 'Modern' and appropriate construction technologies may be complementary. 'Hybrid' technologies, combining suitable 'modern' technologies with appropriate ones should be developed. For example, project programming and resource management tools may be used with labour-intensive technologies. High-volume prefabrication could also be explored in local-materials development if market demand would make scale economies possible.

Construction technologies to be transferred should be carefully selected with regard to their relevance. Those selected should be prioritized considering

1. closeness of fit with existing technologies in the organization/industry;
2. contribution to the development of the company/industry;
3. ease of transfer and dissemination;
4. availability of persons (or organizations) who can benefit from it;
5. direct use (or facilitation of use) of local resources;
6. contribution to labour productivity and corporate/industry efficiency; and
7. stimulation of activities in other sectors of the economy.

These criteria and others may be accorded different weights in various countries and over time.

Efficiency of transfer of construction technologies from local research centres should be improved. R&D in the centres should be given a commercial orientation, by strengthening the identification of need, user targeting and dissemination. Extension services should also be instituted or strengthened.

Effective use and diffusion

Preferably measurable targets and success factors should be articulated in each technology transfer agreement, which should be continually monitored. Significant human resource development programmes may be required with some transferred construction technologies. Some building regulations may also need revision.

The fragmented nature of the construction process should be recognized. Designers should be informed about technologies transferred or developed locally. Continuing professional development and revision of syllabi of construction-related courses to include these technologies, would help achieve this.

International dimension

Cooperation among developing countries should be intensified. They can share knowledge and experiences on technologies and pool R&D effort. This is relevant as a construction technology would be appropriate to many countries in a region. Developing countries could adopt a united stand to improve their bargaining position, for example, by agreeing on approaches to technology transfer which maximize benefits to them and safeguard their interests. To support transfer of 'modern' technologies, cooperation between newly industrializing and developing countries should be increased.

International effort is required to support transfer of appropriate and environmentally-friendly construction technologies. The trend of commercialization in this area should be intensified. Finally, the work on construction technology transfer of international organizations such as the UNCHS, UNCTAD and Intermediate Technology Development Group should be coordinated, consolidated and intensified.

Conclusion

Despite much research and application, technology transfer remains imprecise and shrouded in controversy, emotion and confusion. However, technology transfer offers scope for improving construction industries in developing countries. It should be considered from a broader, more integrated perspective and its complexities recognized. Technology transfer to a country is only the beginning of a long process ending in widespread use and improvement of the technology, hence contributing to the nation's technological development. Governments have a key role to play; international cooperation is essential. However, much depends on the motivation and commitment of technology suppliers and recipients and the latter's ability to exploit opportunities offered.

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