MODELLING A CONCEPTUAL FRAMEWORK OF TECHNOLOGY TRANSFER PROCESS IN CONSTRUCTION PROJECTS: AN EMPIRICAL APPROACH

De-Graft OWUSU-MANU[1], Erika Anneli PÄRN[2], Maxwell Fordjour ANTWI-AFARI[3], and David John EDWARDS[4]

[1]Senior lecturer, Department of Building Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, Email: d.owusumanu@gmail.com
[2]Lecturer, Faculty of Technology Environment and Engineering, Birmingham City University, Birmingham, UK, Email: erika.parn@bcu.ac.uk
[3]Graduate assistant, Department of Building Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, Email: maxbeez279@yahoo.com
[4]Professor of Plant and Machinery Management, Faculty of Technology Environment and Engineering, Birmingham City University, Birmingham, UK, Email: david.edwards@bcu.ac.uk

ABSTRACT
Technology transfer (TT) is crucial to social infrastructure and economic development in developing countries (DCs). In Ghana's construction sector, foreign firms provide an invaluable source of innovation and technological advancement for local contractors. However, TT models published in existing literature are rarely applicable to the construction industry in DCs. This paper therefore presents a conceptual framework of the TT process as a tool for measuring construction performance. Utilising the results from a questionnaire survey of Ghanaian construction industry professionals, eight different perspectives on TT were formulated using exploratory factor analysis. These perspectives represent the enablers and outcomes of the TT process, namely transferor and transferee characteristics, knowledge advancement, the transfer environment, government influence, the learning environment, project performance, communication, and relationship building and absorptive capability. The research outcomes provide useful guidance to local and international funding agencies, governments of developing or newly industrialised countries, and construction firms that seek to effectively evaluate the success (or otherwise) of the TT process. Future research should seek to validate the research findings presented, and to expand the work to include other DCs.

Keywords: Conceptual framework, Ghanaian government, construction, technology transfer

INTRODUCTION
Technology transfer (TT) has been defined as the movement of knowledge and technology from one individual or firm to another (Gibson and Smilor, 1991). In a broader sense, TT encompasses know-how about the transformation of operational technologies and processes, material technologies, and knowledge technologies (Wilson, 1986). TT provides a powerful source of innovation for construction firms that transform and complement current technologies so as to enhance business performance (Nonaka and Takeuchi, 1995). Consequently, TT is an invaluable stimulus for industrialisation and economic growth in developing countries (DCs) (Ganesan and Kelsey, 2006). Many developing and newly industrialised countries lack core technical and

management capabilities to undertake complex infrastructure projects. To more rapidly develop their infrastructure, economies, and living standards, DCs must embrace TT initiatives in the construction and allied industries. However, these initiatives have not immediately translated into enhanced capabilities and competitiveness with firms in the host countries, resulting in continued reliance on foreign competition. In recent decades, TT research has focused mainly on the business and manufacturing sectors (Malik, 2002; Lin and Berg, 2001). Some of these empirical and qualitative studies have produced frameworks or models of the TT process. Yet these models lack robust empirical data analysis, and none of them have linked TT process enablers to identifiable outcomes. Furthermore, existing models cannot be adopted to comprehensively explain interactions between TT process enablers and outcome factors in a construction context. Neither can existing models and frameworks link the TT process with its associated risk and success factors during TT operations (Lewis, 1998; Moxon and Lewis, 1998). To improve the rates of TT process in DCs, this study aims to develop a more comprehensive TT framework that includes factors to quantify causal relationships between transferor and transferee firms. Factors that impact upon TT performance ultimately impinge upon the degree of value added to the local construction sector. According to San (2004), this is especially true in construction firms in DCs, where it was assumed that more rapid improvement in their management and technical capabilities could be achieved through TT initiatives with foreign firms. These measurement indicators of the TT process may be broadly defined as enablers, and they include the transfer environment, the learning environment, transferor and transferee characteristics, government influence, communication, and relationship building and absorptive capability. The performance of, and interaction between, these enablers can influence the degree of value added to the host construction sector, in areas such as knowledge advancement and project performance. The developed conceptual framework of the TT process presented in this paper illustrates the interactions between TT enablers and outcome factors.

CONCEPTUAL BACKGROUND OF TECHNOLOGY AND TECHNOLOGY TRANSFER

According to Kumar et al. (1999), "technology" consists of two primary components: (i) a physical component, which includes products, equipment, techniques, and processes, and (ii) an information component, which includes know-how about management, marketing, production, quality control, reliability, skilled labour, and functional areas. In a construction context, Tatum (1988) refers to construction technology as the combination of construction methods, construction resources, work tasks, and project influences that define the manner of performing a construction operation. As an extension in terminologies, TT has been characterised in various ways, depending on the particular discipline and the purpose of the research (Bozeman, 2000). Gibson and Smilor (1991) opined that TT is often a chaotic, disorderly process involving groups and individuals who may hold different views about the value of TT (Smith and Alexander, 1988). Most authors concur that TT is a complex process that needs time to evolve (Agmon and Glinow, 1991). TT involves a two-way process, which can succeed only when both the donor and the recipient work together to decide what needs to be transferred and implemented (Sridharan, 1994). Moavenzadeh and Hagopian (1984) suggested that involvement of foreign contractors is a key requirement for development of the local construction industry, and they also reported that local contractors progressively enhance their capability by working with foreign contractors, until they can ultimately offer their own services. In the Singaporean construction industry, it is evident that local contractors' capacity and ability have been enhanced through their involvement with foreign firms (Lam, 1997). Such transfers can be successful when the transferee can effectively utilise the technologies transferred and ultimately assimilate them (Ramanathan, 1994). The transfer process may involve physical assets, know-how, and technical knowledge (Bozeman, 2000). As such, the TT process may be confined to relocation and exchange of personnel (Osman-Gani, 1999), or transfer of a specific set of capabilities (Lundquist, 2003).

Towards understanding technology transfer in the construction industry

Technology capabilities are crucial for the development of competitive advantage (Baerz et al., 2010). TT is a potentially powerful source of innovation that can provide construction firms with new technologies, which can appropriately transform and complement current technologies, so as to realise and sustain improved performance (Sexton et al., 1999). TT represents the movement of knowledge and technology via some channel, from one individual or firm to another (Gibson and Smilor, 1991). According to Sexton and Barrett (2004), firms need to understand and manage TT activity, so as to ensure consistent success. Diffusion of innovative technologies in the market is usually complex, and the degree of success varies; the effects of diffused innovative technologies opportunities remain underutilised, and diffusion of innovative technologies thus appears to be slow (Van Egmond and Erkelens, 2007). Forming of joint ventures between local and foreign contractors has been recommended by Henriod (1984), and such integration on construction projects can facilitate transfer of construction technology (Ganesan and Kelsey, 2006; Kumaraswamy, 2006; Sexton and Barrett, 2004). According to Simkoko (1989), the TT process in industrial projects differs from that in construction projects; however, both sectors undergo more or less similar phases in realising the process. Evidence of similarities in life cycles is observed in the following construction project phases: conceptualisation (conception, feasibility studies, and inception), implementation (design, engineering, and construction), and operation, or utilisation. During the construction delivery process, capacities and capabilities are provided concurrently, in the sense that construction techniques are employed in project execution, while know-how, managerial skills, and experience act as necessary inputs on the construction techniques. Thus, integration of both local and foreign technological/managerial capabilities in the project delivery process can facilitate transfer of technological capabilities to DCs (Stewart and Waroonkun, 2007).

A critical review of existing models

Various researchers have studied the TT process and international TT models in mainly the business and the manufacturing sectors (Malik, 2002; Lin and Berg, 2001; Simkoko, 1992). A comprehensive TT model that links TT enablers and outcome factors to construction projects in DCs has not yet been developed (Lin and Berg, 2001). From the existing literature, five TT models were examined that could provide perspectives into conceptualising a TT model for the construction sector in Ghana. These models are the Value-Added Model, the Knowledge Transfer Model, the Extended TT Project Life Cycle Model, the Technology Acquisition Model, and the Comparative Marketing Model (Wang et al., 2004; Saad et al., 2002; Calantone et al., 1990).

The Value-Added (VA) Model

Developed by Waroonkun and Stewart (2008), the VA Model attempts to improve the rate of TT in DCs. The transferee refers to Thai architectural, engineering and construction (AEC) firms, and the transferor refers to foreign AEC firms working with Thai firms to procure projects.

Transferor firms had origins in developed nations, such as the United States, Japan, Germany, the United Kingdom, and Australia. The model sought to denote all significant factors that influence the effectiveness of the TT process and the resulting value added. The classification of variables resulted in five definable factors (constructs), namely (i) the transfer environment, (ii) the learning environment, (iii) transferee characteristics, (iv) transferor characteristics, and (v) the TT value added. The structure of the model and the links between the constructs were based on experimental analysis, and they required testing to confirm their appropriateness and validity.

The Knowledge Transfer (KT) Model

The KT Model developed by Wang et al. (2004) sought to better understand the transfer of knowledge from a multinational company to a subsidiary. Semi-structured interviews with 62 multinational companies operating in China provided an analysis data set that identified two stages in the transfer process. Stage 1 focused on the parent company's contribution of knowledge (i.e. capacity and willingness to transfer), while stage 2 focused on the subsidiary company's acquisition of knowledge (i.e. capacity and intent to learn). The inherent weakness of the model is that it is based on case studies of multinational companies that are generalised to theoretical propositions, and not to the general population.

The Extended TT Project Life Cycle (ETT-PLC) Model

Saad et al. (2002) proposed the Extended TT Project Life Cycle (ETT-PLC) Model, which was used to analyse the TT process in Algeria, utilising two case studies based on two integrated mechanisms of TT used between 1965 and 1990, namely turnkey and product-in-hand. The model specifically considered the contractual arrangements that govern TT projects, but it assumed that the procurement and acquisition of hardware, software, and knowledge are relevant to specific industrial and national cases. A complex range of issues associated with the influence of multiple stakeholders on the TT process were identified. However, the ETT-PLC Model concluded that project success can be classified into four categories: (i) how effectively the project meets both the budget and the schedule, (ii) customer impact or satisfaction, (iii) business or direct success, and (iv) future potential.

The Technology Acquisition (TA) Model

The TA Model developed by Simkoko (1992) focused on TT in the construction industry of DCs. The research by Simkoko (1992) was based on case studies of 12 construction projects in DCs in Africa, South America, and Asia undertaken during 1987 and 1988. The objective was to examine the impact of TT programmes and other internal and external environmental factors on construction project performance. Seven factors that impacted upon the construction project delivery process were (i) the project delivery system, (ii) project management teams, (iii) transfer programmes, (iv) client characteristics, (v) project characteristics, (vi) design and construction technologies, and (vii) project performance. This research represents the only available international TT model tailored for the construction sector. However, the research was limited to development of technological and management practices in the local industry, and it failed to model the TT enabling process. Nevertheless, the model offers some insight into possible enablers and outcome factors that impact upon TT in construction projects.

The Comparative Marketing (CM) Model

Calantone et al. (1990) developed the CM Model for international TT based on concepts formulated by Jean Boddewyn's comparative marketing research (Boddewyn, 1966, 1981). The CM Model presents a system made up of five elements, namely (i) environment, (ii) actors, (iii) structure, (iv) process, and (v) functions. The model is extremely complex in design and has not been empirically verified through a robust statistical analysis. Furthermore, while the model includes a number of factors that could be adapted for utilisation in the construction context, it is largely limited to marketing and logistics. However, the research concluded that TT research investigations should not be restricted to examining the direct effects of identified factors and associated variables, but that it is also important to examine causal interactions between factors, so as to achieve an accurate representation of the TT process. The factors and associated variables identified in this investigation were utilised to develop the conceptual model for international TT in construction projects, which is described next.

Conceptualising technology transfer partnerships

The aim of developing a conceptual model for the TT process in the Ghanaian construction industry is to capture all relevant factors that influence the effectiveness of TT, and their resulting value-added creation. These factors have been adapted from the aforementioned previous work on the phenomenon of TT. Through a process of contextualising and categorising variables and conceptualising their relationship with one another, a number of factors were identified. These factors were classified as enabling factors and TT value-added factors. The classification of variables resulted in eight definable factors, namely (i) transferor and transferee characteristics, (ii) the transfer environment, (iii) relationship building and absorptive capability, (iv) government influence, (v) the learning environment, (vi) communication, (vii) project performance, and (viii) knowledge advancement. The project performance factor and the knowledge advancement factor constituted TT value-added creation. The structure of the conceptual framework constructs and the relationship between them have also been conceptualised based on empirical analysis, and testing is therefore required to confirm their appropriateness and validity.

RESEARCH METHOD

Data was acquired from Ghanaian construction professionals in the third quarter of 2014. The target group of respondents included design and construction professionals who were involved in TT initiatives. This study solicited the perceptions of transferees in Ghana only, since TT initiatives are ultimately undertaken for the purpose of improving knowledge levels and enhancing the industry capacity of host participants. Due to inherent difficulties associated with defining the population of construction professionals in Ghana, purposive and snowballing non-probability sampling techniques were used (Berger and Udell, 1988). In total, 120 survey questionnaires were distributed, and 94 were returned, representing a response rate of 78%. The questionnaire survey contained two distinct sections. Section 1 solicited descriptive statistics on the participating respondent (i.e. firm status, firm existence, and professional experience) and the projects they have been involved in where TT programmes were integrated. Section 2 contained questions relating to the enablers for a successful TT process, including the transfer environment, the learning environment, transferor characteristics, transferee characteristics, economic advancement, knowledge advancement, and project performance. These variables contained sub-factors represented in the conceptual framework. Respondents were requested to provide a rating for these variables, measured on a five-point Likert scale, where response options ranged from 1 ("not significant") to 5 ("very significant"). Statistical techniques including descriptive analysis and exploratory factor analysis were then used to analyse the data collected.

DATA ANALYSIS AND RESULTS

The effect of legal organisation can affect the behaviour of the firm's activity (Owusu-Manu, 2008). Conventional types of legal organisation considered in this study were enterprises/sole proprietorships, private limited liability, and partnerships/joint ventures. These types of firms represent popular legal forms of businesses in both developed and developing countries (Owusu-Manu, 2008). When asked to indicate the type of legal organisation of their firms, a high majority of respondents, representing 57.5%, were operating as private limited liability firms (PLFs), 28.7% were enterprises/sole proprietorships, and the remaining 13.8% were partnerships/joint ventures. These results suggest the perceived advantage of PLFs as a good sign of credibility and formality of operations (Cassar, 2004).

The age of a firm has been recognised as a critical factor in determining the firm's real activity variables, including growth, financing pattern, and employment. For instance, Evans (1987) revealed that growth rate of the firm and volatility of growth are both negatively associated with firm age. Cabral and Mata (2003) demonstrated that the distribution of the logarithms of firm size of a given cohort is skewed to the right at time of birth, and gradually evolves towards a more symmetric distribution. In particular, these authors indicated that the total firm size distribution, in turn, is fairly stable over time, and therefore skewed to the right. In this regard, Stinchcombe (1965) suggested that older firms are more experienced, have learned more over time, are not susceptible to the liability of newness, and have improved performance. Previously, other authors have considered age of vendor firms as a proxy measure for reduction of asymmetric information between a firm and its financiers (Elliehausen and Wolken, 1990; Berger and Udell, 1998). Drawing from these experiences, the age of the firm would also affect the firm's social obligations. The age levels of the sample firms were gathered. Analysis of the data revealed that 33.0% of the sample firms had been in existence for 10 years or less, 14.9% had been in existence for 20 years or less, 37.2% had existed for 30 years or less, and 14.9% had existed for more than 30 years. The age of the firm will determine the experiences of its employees in the acquisition of knowledge and technology in the TT process. A respondent's years of experience in an organisation allow them to acquire more knowledge and experience of TT. An analysis of respondent experience reveals that 22.3% of respondents had less than 5 years' working experience, 43.6% had 10 years or less, 11.7% had 15 years or less, and 22.3% had 20 years or less. The results indicate that survey respondents had reasonable experience and would provide a balanced view of how the TT process is perceived by construction practitioners.

Factor analysis

Factor analysis is based on the correlation matrix of the variables involved. Correlations require a large sample size before they can stabilise, and a bare minimum of 10 observations per variable is necessary to avoid computational difficulties (Hair et al., 1998; DeCoster, 1998). According to Field (2005), Ahadzie (2007), and Owusu and Badu (2009), factor analysis is useful for finding clusters of related variables and is ideal for reducing a large number of variables into a more easily understood framework. The data sample was deemed adequate for factor analysis, exceeding the observation-to-variable ratio recommended by Hair et al. (1998). Furthermore, the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity were used to measure sampling adequacy within factor analysis (Field, 2005). The KMO measure ranges from 0 to 1, where a value of zero indicates that the sum of partial correlations is large relative to the sum of correlations, indicating diffusion in the patterns of correlation, and thus indicating that factor analysis is inappropriate (Field, 2005; Gorsuch, 1983). A value close to 1.00 indicates that the patterns of correlation are relatively compact, and so factor analysis should yield distinct and reliable factors (Field, 2005). However, the literature recommends that the KMO value should be greater than 0.50 if the sample size is adequate (Coakes, 2005; Field, 2005). Table 1 shows that the KMO was approximately 0.638, which confirms the adequacy of the sample size, and indicates that factor analysis can proceed.

Table 1: The Kaiser-Meyer-Olkin measure of sampling adequacy, and the Bartlett's test of sphericity measure

Kaiser-Meyer-Olkin measure of sampling adequacy		.638
Bartlett's test of sphericity measure	Approx. chi-square	2126.103
	df	300
	Sig.	.000

Similarly, the data has 94 observations per variable, and the communalities after extraction were above 0.6 (see Table 2), which further confirms the adequacy of the sample size. The Bartlett's test of sphericity measure is also statistically significant, since the KMO is above 0.5. These data (the KMO, and the Bartlett's test of sphericity measure) indicate that there is a strong relationship between the enablers of TT variables.

Table 2: Communalities

Variable	**Initial**	**After extraction**
1. Complexity of construction technology	1.000	.898
2. Construction mode of transfer	1.000	.751
3. Government policy	1.000	.838
4. Government enforcement	1.000	.853
5. Cultural differences	1.000	.899
6. Trust	1.000	.695
7. Communication	1.000	.645
8. Training programmes	1.000	.798
9. Teamwork	1.000	.725
10. Willingness to transfer	1.000	.617
11. Level of experience (transferee)	1.000	.790
12. Cultural traits (transferor)	1.000	.884
13. Knowledge base (transferee)	1.000	.636
14. Intent to learn technology	1.000	.872
15. Level of experience (transferor)	1.000	.927
16. Cultural traits (transferee)	1.000	.776
17. Knowledge base (transferor)	1.000	.877
18. Competitiveness	1.000	.646

19. Performance improvement	1.000	.693
20. Improved knowledge	1.000	.845
21. Improved working practices	1.000	.764
22. Long-term adoption of transferred skills	1.000	.755
23. Financial performance	1.000	.795
24. Schedule performance	1.000	.686
25. Quality performance	1.000	.846

Method of extraction: principal component analysis

The statistical significance of the Bartlett's test of sphericity measure also suggests that the population was not an identical matrix, and that relationships thus exist between the variables (Field, 2005). The Bartlett's test measure for this study was highly significant ($p<0.001$), and factor analysis is therefore appropriate. Having satisfied the criteria for data suitability, principal component analysis (PCA) and Varimax with Kaiser Normalization were then used to analyse the data collected. A critical examination of the extraction sums of squared loadings in Table 2 reveals that the average of communalities extracted was above 0.60, which indicates how well the extracted components represent the variables. The extracted components are thus a very good representation of the factors that enable TT. Both the Kaiser-Guttman rule and the Cattell scree test were used to determine the number of factors to be extracted. The Kaiser-Guttman rule suggests that only those factors with an eigenvalue greater than 1 should be retained, while the Cattell scree test suggests that all subsequent components after the one starting at the elbow should not be included. After applying these criteria, eight components were extracted to represent the factors that enable TT factors, or the variables.

Table 3: Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cum. %	Total	% of variance	Cum. %	Total	% of variance	Cum. %
1	**4.248**	**16.990**	**16.990**	4.248	16.990	16.990	3.044	**12.178**	**12.178**
2	**3.821**	**15.283**	**32.273**	3.821	15.283	32.273	2.983	**11.933**	**24.111**
3	**2.656**	**10.622**	**42.896**	2.656	10.622	42.896	2.875	**11.502**	**35.612**
4	**2.563**	**10.251**	**53.147**	2.563	10.251	53.147	2.798	**11.192**	**46.804**
5	**2.012**	**8.048**	**61.195**	2.012	8.048	61.195	2.396	**9.584**	**56.387**
6	**1.739**	**6.956**	**68.151**	1.739	6.956	68.151	2.146	**8.584**	**64.971**
7	**1.329**	**5.317**	**73.468**	1.329	5.317	73.468	1.648	**6.594**	**71.565**
8	**1.142**	**4.567**	**78.035**	1.142	4.567	78.035	1.617	**6.470**	**78.035**
9	0.931	3.724	81.759						
10	0.898	3.590	85.349						
11	0.759	3.035	88.384						
12	0.614	2.458	90.842						
13	0.517	2.067	92.908						
14	0.470	1.879	94.788						
15	0.327	1.309	96.097						
16	0.261	1.044	97.141						
17	0.219	0.876	98.017						

18	0.158	0.633	98.650		
19	0.125	0.500	99.150		
20	0.075	0.301	99.451		
21	0.053	0.210	99.661		
22	0.041	0.163	99.824		
23	0.019	0.075	99.900		
24	0.014	0.055	99.955		
25	0.011	0.045	100.000		

Method of extraction: principal component analysis

The total variance explained by each component extracted was 16.990% for component 1, 15.283% for component 2, 10.622% for component 3, 10.251% for component 4, 8.048% for component 5, 6.956% for component 6, 5.317% for component 7, and 4.567% for component 8. In all, the eight components extracted cumulatively accounted for 78.035% of the variation inherent in the data. This therefore implies that eight principal components have been extracted to represent key enablers of TT whose eigenvalues are greater than 1. Rotation can improve the interpretability of results (Norušis, 2005). The rotated factor solution is displayed by default and is essential for interpreting the final rotated analysis. Rotation suggests the behaviour of the variables under extreme conditions; it maximises the loading of each variable on one of the extracted factors, while minimising the loading on all the other factors (Child, 1990). Tables 4 and 5 present the results of the component matrix and the rotated component matrix, respectively, of the principal component analysis.

Table 4: Component matrix[a]

Variable	**Component**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Complexity of construction technology	.278	-.677	.319	-.210	-.139	.369	-.248	-.012
Construction mode of transfer	.652	-.390	.237	-.189	.117	.083	-.233	.087
Government policy	-.206	.579	.502	.349	.179	.009	.176	.154
Government enforcement	-.467	.434	.604	.118	.136	-.100	.121	.157
Cultural differences	-.554	.265	.547	-.019	-.091	.440	.105	.094
Trust	-.088	-.311	.458	.075	.413	.033	.204	-.403
Communication	.226	.038	.114	-.136	.251	-.527	-.337	.326
Training programmes	.480	.068	.300	-.137	-.249	-.578	.204	.129
Teamwork	.029	.600	.426	-.009	-.080	-.160	-.320	.218
Willingness to transfer	.262	-.608	.053	-.077	.232	.170	-.065	.288
Level of experience (transferee)	.421	.518	-.001	-.395	.272	-.043	-.299	-.153
Cultural traits (transferor)	.594	.101	.217	-.479	.180	-.170	.277	-.325
Knowledge base (transferee)	.095	.555	-.413	-.210	.153	.036	-.214	.185
Intent to learn technology	.425	-.273	-.204	-.076	-.276	.242	.367	.549
Level of experience (transferor)	.316	.556	-.110	-.291	.211	.601	.012	-.123
Cultural traits (transferee)	.459	.037	.179	-.522	-.181	-.213	.415	-.089
Knowledge base (transferor)	.348	.732	-.175	-.326	-.006	.270	.100	.033
Competitiveness	.535	-.048	.413	.270	.075	.082	.286	.142
Performance improvement	.608	.185	.324	.236	.013	.318	-.150	.069
Improved knowledge	.672	.238	-.025	.513	-.256	.067	-.018	-.053
Improved working practices	.438	.161	-.123	.581	-.287	-.082	-.039	-.321
Long-term adoption of transferred skills	.483	-.010	.263	.534	-.251	.012	-.294	-.131

Financial performance	.110	-.342	.199	.079	.775	-.035	-.130	.002
Schedule performance	.253	-.012	-.255	.415	.516	.085	.296	.152
Quality performance	.244	.202	-.534	.455	.445	-.166	.162	.040

Method of extraction: principal component analysis
[a]: eight components extracted

The next stage sought to examine the presence of any complex structure among the variables. A complex structure is present when a variable has a factor or component loading greater than 0.50 on more than one component. Loadings express the influence of each original variable within the component. After checking for the presence of a complex structure in the variables, the factor loadings are again examined, but this time to check for components that have only one variable loading on them. Table 5 shows that all eight components had more than one variable loading on them, and all eight components were therefore retained. What remains is the interpretation of the eight principal components extracted. Note that the original 25 variables have been dimensionally reduced into eight new intercorrelated variables, which explain 78% of the total variance in the variables included on the components. These results show that these factors are significant indicators of enablers of TT in the Ghanaian construction industry.

Table 5: Rotated component matrix[a]

Variable	**Component**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Complexity of construction technology	-.156	.088	**.794**	-.230	.021	-.395	-.153	.051
Construction mode of transfer	.086	.228	**.722**	-.232	.256	-.057	.213	.057
Government policy	.071	.143	-.212	**.855**	-.021	.164	.039	.094
Government enforcement	-.079	-.142	-.211	**.861**	-.016	-.075	.101	.159
Cultural differences	.032	-.198	.005	**.757**	-.206	-.342	-.354	.023
Trust	-.260	-.073	.256	.187	.175	.108	-.242	**.649**
Communication	.011	-.041	.127	.008	.128	.070	**.777**	.032
Training programmes	-.154	.239	-.031	.056	**.718**	-.072	.402	-.176
Teamwork	.286	.210	-.143	.541	.009	-.264	.464	-.034
Willingness to transfer	-.174	-.104	.712	-.203	-.016	.146	.051	-.063
Level of experience (transferee)	.745	.074	-.013	-.049	.224	-.045	.353	.225
Cultural traits (transferee)	.340	.035	.150	-.121	.808	.021	.037	.272
Knowledge base (transferee)	.639	-.103	-.242	-.071	-.147	.138	.272	-.199
Intent to learn technology	-.041	.033	.400	-.163	.234	.187	-.174	-.750
Level of experience (transferor)	.908	.049	.086	.085	.041	.069	-.281	.007
Cultural traits (transferor)	.137	-.045	.062	-.092	.843	-.139	-.014	-.111
Knowledge base (transferor)	.844	.069	-.184	.103	.231	.043	-.057	-.240
Competitiveness	-.065	.430	.396	.290	.371	.269	-.056	-.056
Performance improvement	.319	.610	.402	.218	.078	.054	.018	-.030
Improved knowledge	.147	.856	-.005	-.043	.113	.194	-.013	-.194
Improved working practices	-.034	.802	-.251	-.176	.028	.138	-.070	.013
Long-term adoption of transferred skills	-.101	.836	.159	.022	-.042	-.073	.099	.060
Financial performance	-.073	-.146	.509	.033	-.071	.420	.225	.525
Schedule performance	.039	.106	.126	.005	-.054	.806	-.071	.001
Quality performance	.127	.181	-.241	-.186	-.107	.824	.118	.002

Method of extraction: principal component analysis
Rotation method: Varimax with Kaiser Normalization
[a]: Rotation converged in 16 iterations

DISCUSSION AND INTERPRETATION OF RESULTS

To discuss and interpret the results, the procedure proposed by Leedy and Ormrod (2005) was adopted, which relates the research findings to hypotheses advanced, connects the findings to existing literature, concepts, theories, and previous research studies, determines if the findings have practical and statistical significance, and identifies limitations of the research. Based on a critical examination of the inherent relationships among the variables under each component, the following underlying dimensions were deduced: component 1: transferor and transferee characteristics; component 2: knowledge advancement; component 3: transfer environment; component 4: government influence; component 5: learning environment; component 6: project performance; component 7: communication; component 8: relationship building. These labels were derived based on the interrelated characteristics of the variables, and their combination with high factor loadings.

Component 1: Transferor and transferee characteristics (PC1)

PC1 in Table 6 reported high factor loadings for the variables "level of experience (transferee)" (0.745), "knowledge base (transferee)" (0.639), "level of experience (transferor)" (0.908), and "knowledge base (transferor)" (0.844).

Table 6: Component profile of the enablers of TT

Description of components and variables	Factor loading	Variance explained
Component 1: Transferor and transferee characteristics		
1. Level of experience (transferee)	.745	**16.990%**
2. Knowledge base (transferee)	.639	
3. Level of experience (transferor)	.908	
4. Knowledge base (transferor)	.844	
Component 2: Knowledge advancement		
1. Performance improvement	.610	**15.283%**
2. Improved knowledge	.856	
3. Improved working practices	.802	
4. Long-term adoption of transferred skills	.836	

Component 3: Transfer environment		
1. Complexity of construction technology	.794	**10.622%**
2. Construction mode of transfer	.722	
3. Willingness to transfer	.712	
Component 4: Government influence		
1. Government policy	.855	**10.251%**
2. Government enforcement	.861	
3. Cultural differences	.757	
Component 5: Learning environment		
1. Training programmes	.718	**8.048%**
2. Cultural traits (transferee)	.808	
3. Cultural traits (transferor)	.843	
Component 6: Project performance		
1. Schedule performance	.806	**6.956%**
2. Quality performance	.824	
Component 7: Communication		
1. Communication	.777	**5.317%**
Component 8: Relationship building and absorptive capability		
1. Trust	.649	**4.567%**
2. Intent to learn technology	-.750	

The values in brackets indicate the respective factor loadings, which assume the relative importance of the variable in the data set of the component. The cluster of variables in component 1 accounted for 16.990% of the variance explained, as shown in Table 3. The chi-square test revealed that there was a significant key relationship between level of experience, knowledge base, level of experience, and knowledge base as enablers of TT.

Component 2: Knowledge advancement (PC2)

PC2 in Table 6 reported high factor loadings for the variables “performance improvement” (0.610), “improved knowledge” (0.856), “improved working practices” (0.802) and “long-term adoption of transferred skills” (0.836). The component accounted for 15.283% of the variance explained, as shown in Table 3. The chi-square test for significance revealed that a significant key relationship exists between performance improvement, improved knowledge, improved working practices, and long-term adoption of transferred skills as enablers of TT.

Component 3: Transfer environment (PC3)

The variables extracted under PC3 include “complexity of construction technology”, “construction mode of transfer”, and “willingness to transfer”, with eigenvalues of 0.794, 0.722, and 0.712, respectively. The component accounted for 10.622% of the variance explained, as shown in Table 3. The chi square test failed to reject the null hypothesis relation to construction mode of transfer, hence, it is not dependent on the transfer environment as an enabler of TT. However, the chi square test revealed that there is statistical evidence to advocate the dependency of complexity of construction technology and willing to transfer were dependent on the transfer environment as enablers of TT.

Component 4: Government influence (PC4)

The variables extracted under PC4 include “government policy”, “government enforcement”, and “cultural differences”, with eigenvalues of 0.855, 0.861, and 0.757, respectively. The component accounted for 10.251% of the variance, as shown in Table 3. The chi square test rejected the null hypothesis for all extracted variables, hence, there is a statistical evidence of dependency amongst these variables upon government influence as an enabler of TT.

Component 5: Learning environment (PC5)

The variables extracted under PC5 include “training programmes”, “cultural traits (transferee)”, and “cultural traits (transferor)”, with eigenvalues of 0.718, 0.808, and 0.843, respectively. The component accounted for 8.048% of the variance (see Table 3). The chi square test rejected the null hypothesis for all extracted variables, hence statistical evidence of dependency amongst these variables upon the learning environment as an enabler of TT.

Component 6: Project performance (PC6)

The variables extracted under PC6 include “schedule performance” and “quality performance”, with eigenvalues of 0.806 and 0.824, respectively. The component accounted for 6.956% of the variance explained (see Table 3). The component accounted for 6.956% of the variance explained (refer to Table 3). The chi square test rejected the null hypothesis in relation to all extracted variables, hence, there is statistical evidence of dependency amongst these variables upon the project performance as an enabler of TT.

Component 7: Communication (PC7)

The variable extracted under PC7 is “communication”, with an eigenvalue of 0.777. The extracted component accounted for 5.317% of the variance explained (see Table 3). The chi square test rejected the null hypothesis relation to the extracted variable, hence there is statistical evidence of dependency amongst these variables upon communication as an enabler of TT. Previous authors have stressed the importance of effectiveness of communication between transferor and transferee and its impact on the TT process (Devapriya and Ganesan, 2002; Ganesan and Kelsey, 2006; Malik, 2002).

Component 8: Relationship building and absorptive capability (PC8)

The variables extracted under PC8 include “trust” and “intent to learn technology”, with eigenvalues of 0.649 and -0.750, respectively. The component accounted for 4.567% of the variance explained (see Table 3). The chi square test rejected the null hypothesis relation to the extracted variable, hence there is statistical evidence of dependency amongst these variables upon relationship building and absorptive capability as an enabler of TT. For TT to function efficiently and effectively, organisations involved in the TT process should build a culture of mutual trust, through effective communication between transferor and transferee (Malik, 2002). Cohen and Levinthal (1990) adjusted this macroeconomic concept and viewed absorptive capacity as a firm-level construct. Cohen and Levinthal (1989) introduced the absorptive capacity construct as the firm’s ability to identify, assimilate, and exploit knowledge from the environment. They argue that absorptive capacity depends greatly on prior related knowledge and diversity of background. They assume that a firm’s absorptive capacity tends to develop cumulatively and is dependent on the absorptive capacity of its individual members.

Using these eight components and variables, a conceptual framework that reflects TT in the Ghanaian construction sector was constructed (see Figure 1). This model illustrates the typologies of technology that impact upon transferor characteristics, and their interaction with the transfer environment. These aforementioned factors, together with facilitating success factors and risk factors, impact upon the transferee characteristics that lead to TT value-added creation and its links with knowledge advancement and project performance. Further qualitative work is, however, required to develop new concepts and theories, so as to provide a richer explanation of the factors and variables uncovered in this research. To simply state that a variable or factor is statistically significant does not explain why it is significant. Any such further work would almost certainly complement this research and could form the basis for future tools that assess and evaluate the performance of TT in the construction sector of DCs. Such tools are urgently needed, as current means of evaluation are largely subjective and/or impractical to implement.

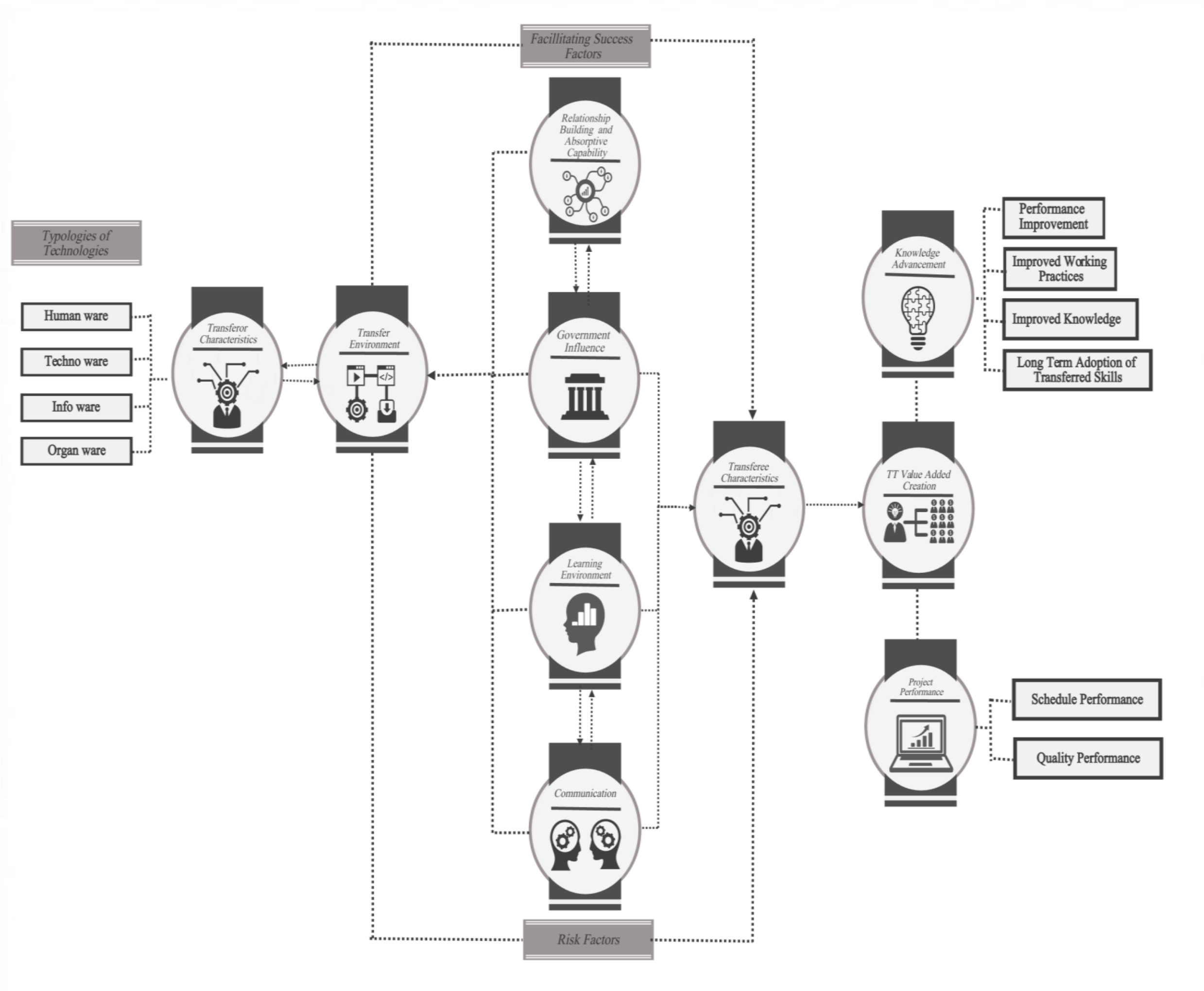

Figure 1: A conceptual framework for technology transfer partnerships

CONCLUSIONS

This study examined the prospect of technology transfer (TT) promoting development of construction companies in host developing countries (DCs), as receivers and users of construction technology. A review of existing TT literature provided a comprehensive understanding of the evolution and development of previous TT models, and the significant influence of knowledge advancement and project performance in shaping current and future TT models. In other industrial sectors, TT initiatives represent the first step towards efficiently and effectively transforming or re-engineering traditional business processes, and ultimately improving productivity performance. In a construction context, more research should be conducted to exploit the inherent potential of TT and expand upon the largely qualitative research conducted within this paper. TT does not, however, occur naturally, and so the processes that underpin TT should be continuously evaluated, so as to ensure that knowledge and skills are being seamlessly absorbed by indigenous workers. The derived TT framework could be utilised to assist government officers in DCs to better evaluate TT performance. TT stakeholders will also benefit from knowledge of the significant pathways to achieving value from the TT process. Understanding the dynamics of such pathways (perhaps using system dynamics) will assist industry and government to better structure TT arrangements and concentrate on the most empowering enablers.

The conceptual framework presented is especially important for publicly funded infrastructure in Ghana, where the government is concerned about whether advanced technologies are being willingly and effectively transferred to local workers and professionals. In addition, the framework could assist multilateral funding agencies, such as the World Bank, which need tools to better monitor the performance of the TT process and provide loans for infrastructure development. One of the primary objectives of these funding agencies is to actively encourage domestic firms in DCs to improve the knowledge levels of their workers, as well as industry capacity, ultimately leading to improved standards of living for all indigenous people. Future studies should seek to determine the relationship between perceptions of culture, physical environment, and geographical location and the success of TT. In addition, the conceptual model presented must be validated using system dynamics, structural equations, and/or methods of benchmarking, so as to strengthen evaluation of baseline performance of the construction TT process in Ghana and other DCs.

ACKNOWLEDGEMENT

This article was language-edited by a freelance language editor, Anthony Sparg. He has edited several academic journal articles and master's theses in the field of construction management. He has an MA *cum laude* in African Languages (isiXhosa), an MA *cum laude* in Linguistics, and a Higher Diploma in Education.

REFERENCES

Agmon, T. and Glinow, V.M. (eds). (1991). *Technology transfer in international business*. New York: Oxford University Press.

Ahadzie, D.K. (2007). *A model for predicting the performance of project managers in mass house building projects in Ghana*. PhD thesis. Wolverhampton, UK: University of Wolverhampton.

Baerz, A.M., Abbasnejad, T., Rostamy, A.A.A. and Azar, A. (2010). Exploring of the role and position of institutional actors in the university-industry interactions. *World Applied Sciences Journal*, 11(11), 1432–1438.

Berger, A.N. and Udell, G.F. (1998). The economics of small business finance: The roles of private equity and debt markets in the financial growth cycle. *Journal of Banking & Finance*, 22(6–8), 613–673.

Boddewyn, J.J. (1966) A Construct for Comparative Marketing Research, Journal of Marketing Research, Vol. 3, No. 2, pp. 149-153.

Boddewyn, J.J. (1981) Comparative Marketing: The First Twenty-Five Year, Journal of International Business Studies, Vol.12, No. 1, pp. 61-79.

Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Research Policy*, 29(4–5), 627–655.

Cabral, L.M.B. and Mata, J. (2003). On the evolution of the firm size distribution: Facts and theory. *American Economic Review*, 93(4), 1075–1090.

Calantone, R.J., Lee, M.-T. and Gross, A.C. (1990). Evaluating international technology transfer in a comparative marketing framework. *Journal of Global Marketing*, 3(3), 23–46.

Cassar, G. (2004). The financing of business start-ups. *Journal of Business Venturing*, 19(2), 261–283.

Child, D. (1990). *The essentials of factor analysis*. 2nd ed. London: Cassel Educational Ltd.

Coakes, S.J. (2005). *SPSS: Analysis without anguish: Version 12.0 for Windows*. Sydney, Australia: John Wiley & Sons Australia.

Cohen, W.M. and Levinthal, D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), 128–152.

Cohen, W.M. and Levinthal, D.A. (1989). Innovation and learning: The two faces of R&D. *The Economic Journal*, 99(397), 569–596.

DeCoster, J. (1998). *Overview of factor analysis*. Tuscaloosa, AL: Department of Psychology, University of Alabama.

Devapriya, K.A.K. and Ganesan, S. (2002). Technology transfer through subcontracting in developing countries. *Building Research & Information*, 30(3), 171–182.

Elliehausen, G.E. and Wolken, J.D. (1990). *Banking markets and the use of financial services by small and medium-sized businesses (Staff Studies 160)*. Washington, DC: Board of Governors of the Federal Reserve System.

Evans, D.S. (1987). The relationship between firm growth, size, and age: Estimates for 100 manufacturing industries. *The Journal of Industrial Economics*, 35(4), 567–581.

Field, A. (2005). *Discovering statistics using SPSS for Windows*. 2nd ed. London: Sage.

Ganesan, S. and Kelsey, J. (2006). Technology transfer: International collaboration in Sri Lanka. *Construction Management and Economics*, 24(7), 743–753.

Gibson, D.V. and Smilor, R.W. (1991). Key variables in technology transfer: A field-study based empirical analysis. *Journal of Engineering and Technology Management*, 8(3–4), 287–312.

Gorsuch, R.L. (1983). *Factor analysis*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998). *Multivariate data analysis*. Upper Saddle River, NJ: Prentice-Hall.

Henriod, E.E. (1984). *The construction industry: Issues and strategies in developing countries*. Washington, DC: World Bank.

Kumar, V., Kumar, U. and Persaud, A. (1999). Building technological capability through importing technology: The case of Indonesian manufacturing industry. *The Journal of Technology Transfer*, 24(1), 81–96.

Kumaraswamy, M.M. (2006). Accelerating construction industry development. *Journal of Construction in Developing Countries*, 11(1), 73–96.

Lam, A. (1997). Embedded firms, embedded knowledge: Problems of collaboration and knowledge transfer in global cooperative ventures. *Organization Studies*, 18(6), 973–996.

Leedy, P.D. and Ormrod, J.E. (2005). *Practical research: Planning and design*. 8th ed. Upper Saddle River, NJ: Pearson Prentice Hall.

Lewis, P. (1998). Trunkliner program scrapped. *Flight International*, 29 July – 4 August, 4.

Lin, B.-W. and Berg, D. (2001). Effects of cultural difference on technology transfer projects: An empirical study of Taiwanese manufacturing companies. *International Journal of Project Management*, 19(5), 287–293.

Lundquist, D.G. (2003). A rich vision of technology transfer technology value management. *The Journal of Technology Transfer*, 28(3/4), 284–312.

Malik, K. (2002). Aiding the technology manager: A conceptual model for intra-firm technology transfer. *Technovation*, 22(7), 427–436.

Moavenzadeh, F. and Hagopian, F. (1984). The construction industry and economic growth. *Asian National Development*, June/July, 56–60.
Moxon, J. and Lewis, P. (1998). Airbus industries and AVIC abandon AE31X. *Flight International*, 8–14 July, 6.
Nonaka, I. and Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.
Norušis, M.J. (2005). *The SPSS guide to data analysis for SPSS-X*. Chicago: SPSS Inc.
Osman-Gani, A.A.M. (1999). International technology transfer for competitive advantage: A conceptual analysis of the role of HRD. *Competitiveness Review: An International Business Journal*, 9(1), 9–23.
Owusu, M.D. and Badu, E. (2009). Determinants of contractors' capital investment finance strategy in Ghana. *Journal of Financial Management of Property and Construction*, 14(1), 21–33.
Owusu-Manu, D. (2008). *Equipment investment finance strategy for large construction firms in Ghana*. PhD dissertation. Department of Building Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
Ramanathan, K. (1994). The polytrophic components of manufacturing technology. *Technological Forecasting and Social Change*, 46(1), 20–35.
Saad, M., Cicmil, S. and Greenwood, M. (2002). Technology transfer projects in developing countries—furthering the Project Management perspectives. *International Journal of Project Management*, 20(8), 617–625.
San, M.M. (2004). Technology transfer a need for development of building sector. *The Myanmar Times*. Available at: http://www.myanmar.com/myanmartimes/MyanmarTimes12-235/025.htm
Sexton, M. and Barrett, P. (2004). The role of technology transfer in innovation within small construction firms. *Engineering, Construction and Architectural Management*, 11(5), 342–348.
Simkoko, E.E. (1989). *Analysis of factors impacting technology transfer in construction projects: Case studies from developing countries*. Stockholm, Sweden: Swedish Council for Building Research.
Simkoko, E.E. (1992). Managing international construction projects for competence development within local firms. *International Journal of Project Management*, 10(1), 12–22.
Smith, D.K. and Alexander, R.C. (1988). *Fumbling the future: How Xerox invented, then ignored, the first personal computer*. New York: William Morrow.
Sridharan, G. (1994). Managing technology transfer in construction joint ventures. *American Association of Cost Engineers Transactions, Morgantown*, 15, 6.1–6.4.
Stewart, R.A. and Waroonkun, T. (2007). Benchmarking construction technology transfer in Thailand. *Construction Innovation: Information, Process, Management*, 7(3), 218–239.
Stinchcombe, A.L. (1965). Social structure and organizations. In: J. G. March (ed.). *Handbook of organizations*. Chicago: Rand McNally.
Tatum, C.B. (1988). Classification system for construction technology. *Journal of Construction Engineering & Management*, 114(3), 334–363.
Van Egmond, E. and Erkelens, P. (2007). Technology and knowledge transfer for capability building in the Ghanaian construction industry. *Construction for Development*,

Information and Knowledge Management in Building (W102), CIB World Building Congress. 14–17 May. Cape Town. pp. 1393–1405.
Wang, P., Tong, T.W. and Koh, C.P. (2004). An integrated model of knowledge transfer from MNC parent to China subsidiary. *Journal of World Business*, 39(2), 168–182.
Waroonkun, T. and Stewart R.A. (2008). Modeling the international technology transfer process in construction projects: Evidence from Thailand. *The Journal of Technology Transfer*, 33(6), 667–687.
Wilson, I. (1986). The strategic management of technology: Corporate fad or strategic necessity? *Long Range Planning*, 19(2), 21–22.